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ROCKWELL INTERNATIONAL
NORTH AMERICAN SPACE OPERATIONS
ROCKY FLATS PLANT

Remedial Investigation Report for High Priority Sites

(881 Hillside Area)

Volume V

U.S. DEPARTMENT OF ENERGY

Rocky Flats Plant
Golden, Colorado

1 MARCH 1988

ADMIN RECORD

REVIEWED FOR CLASSIFICATION/UCNI
By K L Dalhaus
Date 9/20/91

Appendix A

APPENDIX A

SAMPLING PLAN

REVIEWED FOR CLASSIFICATION/UCNI
By K. L. Dalgaard (UNR)
Date 9/30/91

DEPARTMENT OF ENERGY
ALBUQUERQUE OPERATIONS OFFICE
ENVIRONMENT, SAFETY AND HEALTH DIVISION
ENVIRONMENTAL PROGRAMS BRANCH

COMPREHENSIVE ENVIRONMENTAL ASSESSMENT AND RESPONSE PROGRAM

PHASE 2:
ROCKY FLATS PLANT
SITE-SPECIFIC MONITORING PLAN

(Work Plan for Performance of Remedial Investigations and Feasibility Studies for all High-Priority Sites)

SAMPLING PLAN

February 1987

DRAFT

TABLE OF CONTENTS

TABLES

1. INTRODUCTION

CEARP Phase 2 Confirmation consists of CEARP Phase 2a, Monitoring Plan, and CEARP Phase 2b, site characterization (remedial investigation). The Sampling Plan is one component of the Monitoring Plan for Rocky Flats Plant. The Monitoring Plan typically consists of five parts: Synopsis, Sampling Plan, Technical Data Management Plan, Health and Safety Plan, and Quality Assurance/Quality Control (QA/QC) Plan. Because of the Compliance Agreement made by the State of Colorado, Environmental Protection Agency, and Department of Energy (DOE), this Monitoring Plan also includes a Feasibility Study Plan.

CEARP uses a three-tiered approach in the preparation of monitoring plans: the CEARP Generic Monitoring Plan, the Installation Generic Monitoring Plan (IGMP), and Site Specific Monitoring Plans (SSMPs). This SSMP serves as the Work Plan for Performance of Remedial Investigations and Feasibility Studies for all High-Priority Sites required by the Compliance Agreement. Therefore, the acronym used to refer to this plan is SSMP/RIFS. This Rocky Flats Plant SSMP/RIFS Sampling Plan is the detailed work plan for implementation of CEARP Phase 2b site characterizations (remedial investigations) at Rocky Flats Plant and follows guidance provided in the IGMP/CSPCP. This SSMP/RIFS Sampling Plan is complemented by and inseparable from the Technical Data Management Plan and the Quality Assurance/Quality Control Plan. Sections of the Sampling Plan are supported by reference to the other plans and to the Synopsis. Emphasis is placed on integration of efforts for each of the CEARP Phases: Phase 3 (Technological Assessment), Phase 4 (Remedial Action), and Phase 5 (Compliance Verification and Monitoring).

Sampling at Rocky Flats Plant will be conducted using the integrated approach being implemented by CEARP. The integrated approach is summarized in the Synopsis and detailed here. The integrated approach includes characterization in stages, in which the results from the previous stage of sampling are used to design the next stage. This iterative process incorporates the experience and knowledge gained from each stage to minimize the total number of samples required to adequately characterize the site and to provide the necessary data base to prepare feasibility studies for alternative remedial actions. The benefit of staged sampling is greater flexibility within the sampling program with a minimum of cost.

1.1. PURPOSE

This SSMP/RIFS Sampling Plan provides the following basic components of sample/measurement collection and analysis for each high-priority site at Rocky Flats Plant:

- objectives and goals of the investigation
- justification for selected methods and procedures
- proposed sample locations
- proposed number and type of samples
- additional site-specific information requirements.

1.2. OBJECTIVES

The objectives of CEARP Phase 2b site characterizations (remedial investigations) at the high-priority sites at Rocky Flats Plant are to

- verify and characterize contaminant sources,

- determine the present areal and vertical extent of contamination,

- estimate the potential for contaminant migration (including rate and direction) to support risk assessment studies,

- support the technological assessments (feasibility studies) of alternative response actions, including the alternative of "no action," and

- support identification of long term monitoring and verification requirements, as appropriate.

2. SITE SURVEY AND MAPPING

Following the guidance in the IGMP/CSPCP Sampling Plan, all monitoring locations will be described in accordance with the Installation Coordinate System (ICS) for Rocky Flats Plant. The existing coordinate system is a grid system in English units (feet). Elevations will be described in English units, feet above MSL. Surveying will be done in conformance with surveying procedures established in the IGMP/CSPCP.

3. SITE-SPECIFIC MONITORING

Environmental conditions at Rocky Flats Plant have been monitored since shortly after operations began in 1952. In addition, special programs to characterize waste streams, environmental conditions, and past waste disposal practices have been conducted recently (DOE 1986b and DOE 1986f). CEARP Phase 1 identified approximately 70 sites or groupings of sites that could have adverse impacts on the environment. Additional data collected during preparation of the RCRA Part B Operating Permit Application identified several more potential sites. All potential sites at Rocky Flats Plant were designated as solid waste management units, assigned a reference number, and located on a base map (IGMP/CSPCP Sampling Plan, Plate 1).

A list of solid waste management units is presented in Appendix 1 of the RCRA Part B Operating Permit Application (3004[u] Waste Management Units) (DOE 1986f). These solid waste management units are divided into three categories. The first category includes those hazardous waste management units which will continue to operate and which require a RCRA Operating Permit. The second category includes those hazardous waste management units which are being closed under RCRA Interim Status. The third category includes those inactive waste management units (i.e., RCRA continuing release sites) that are identified under Section 3004(u) of RCRA. Another class of sites is regulated under CERCLA. These CERCLA areas identified at Rocky Flats Plant contain only radioactive wastes (DOE 1986f). However, for ease in referencing these units and/or areas, they have been collectively termed solid waste management units. A preliminary prioritization of solid waste management units based on the CEARP Phase I Installation Assessment was performed and summarized in a report titled "Preliminary Prioritization of Sites" (DOE 1986h).

The high-priority sites addressed in this SSMP/RIFS Monitoring Plan were selected and designated as high-priority sites because of their suspected relationship to preliminarily-identified contaminant plumes in groundwater. Several solid waste management units are included in most of the high-priority sites (Table 3.1 Synopsis) because of their physical proximity to each other. This results in high-priority sites that contain solid waste management units from various phases of CEARP. This is consistent with the staged approach being used by CEARP for site characterizations (remedial investigations), where the higher priority solid waste management units within the high-priority sites are investigated first, and data from these characterizations (investigations) guide the remainder of the program.

The six high-priority sites identified at Rocky Flats Plant (Plate 1) are as follows:

- 881 Hillside Site
- 903 Pad Area Site
- Mound Area Site
- East Burial Trenches Site

The three viable pathways for releases of contaminants from Rocky Flats Plant are air, surface water, and groundwater (DOE 1986b). Air pathway characterization studies will not be performed under CEARP, as the air pathway has been adequately characterized and documented by previous studies (DOE 1986b, RI 1986b). A site-specific discussion of the other pathways at each high-priority site is presented after each site description. A plant-wide discussion of pathways is presented in the *SSMP/RIFS Synopsis*.

Investigations at each high-priority site can be divided into source characterization, and migration pathway and plume characterization. Source characterization will generally consist of geophysical surveys, soil gas surveys and soil/waste sampling. Migration pathway and plume characterization will generally include geophysical surveys, soil gas surveys, soil sampling, monitor well installation, groundwater sampling, and surface water and sediment sampling. All CEARP Phase 2b site characterizations (remedial investigations) will be implemented using an integrated approach, in which geophysical and soil gas survey results are used to direct soil and groundwater sampling efforts.

Invasive sampling will be performed at many of the high-priority sites. General criteria that are considered in the sampling descriptions of this plan are as follows:

- If the solid waste management unit cannot be located through geophysical techniques, its suspected location will be sampled.

- Invasive samples from a solid waste management unit will be taken only if the presence of containers of liquid or other hazardous conditions is not anticipated.

- At least six samples will be submitted for laboratory analysis from each borehole depending on the amount of available material. The reader is referred to Section 6 of the IGMP Sampling Plan for rationale.

The following sections present high-priority site descriptions including discussions of associated solid waste management units and migration pathways, followed by detailed plans for source and migration pathway and plume characterization. Complete descriptions of the solid waste management units are contained in the RCRA Part B Operating Permit, Appendix 1 (DOE 1986f).

3.1. 881 HILLSIDE SITE

3.1.1. Site Description

3.1.1.1. Solid Waste Management Unit Descriptions

The 881 Hillside Site has been the site of various spills and disposal operations during the history of the plant. The ten solid waste management units (SWMUs) that make up the 881 Hillside Site are described below.

- Oil Sludge Pit (SWMU Ref. No. 102) - In 1958, approximately 30 to 50 drums of oil sludge from cleaning storage tanks were emptied into a pit south of Building 881 and covered with soil.

- Chemical Burial (SWMU Ref. No. 103) - An area south of Building 881 was reportedly used to bury unknown chemicals.

- Liquid Dumping (SWMU Ref. No. 104) - Prior to 1969, the area east of Building 881 was reportedly used for dumping liquid and disposing of empty drums. The types of liquids and residual materials in the drums is unknown.

- Out-of-Service Fuel Tanks (SWMU Ref. No. 105) - Asbestos was reportedly placed in two out-of-service No. 6 fuel oil tanks located south of Building 881. The tanks were then filled with concrete.

- Outfall (SWMU Ref. No. 106) - An outfall south of Building 881 may discharge on an occasional basis. The outfall is apparently a cleanout pipe for an overflow line from a cooling tower.

- Hillside Oil Leak (SWMU Ref. No. 107) - In 1973, No. 6 fuel oil from an undetermined source was observed on the hillside south of Building 881. Straw was used to limit the spread of the oil. The oil-soaked straw and soil were removed and placed in the present landfill.

- Multiple Solvent Spills (SWMU Ref. No. 119) - In 1967, two areas east of Building 881 and along the southern perimeter road were used as solvent storage facilities. Minor leaks and spills may have occurred in these areas. The facilities were removed by April, 1972.

- Radioactive Site - 800 Area Site #1 (SWMU Ref. No. 130) - An area east of Building 881 was used for the disposal of 320 tons of plutonium-contaminated soil (about 7 dpm/g alpha activity) from the Building 776 fire. The area was also used for the disposal of approximately 60 cubic yards of plutonium-contaminated soil (about 250 dpm/g alpha activity) from the Building 774 waste storage tank area. Site #1 was covered with about 1 to 2 ft of soil.

- Sanitary Waste Line Leak (SWMU Ref. No. 145) - In January 1981, the sanitary waste line located south of Building 881 leaked. An earthen dike was constructed to prevent runoff into the south interceptor ditch and the line was repaired. The sanitary waste line carried radioactive laundry effluent from about 1969 to 1973. Whether other hazardous materials have ever been carried in the line is unknown.

- Building 885 Drum Storage Area (SWMU Ref. No. 177) - The Building 885 Drum Storage Area will be closed under Interim Status (40 CFR 265). Complete information on this solid waste management unit is provided in the Interim Status closure plan.

3.1.1.2. Surface Water

The 881 hillside is a south-facing slope leading from the Rocky Flats Alluvium surface down to Woman Creek. The slope is crossed by several roads and a small drainage, all of which influence runoff patterns. In addition, the south interceptor ditch crosses the lower slope and collects runoff from the hillside.

3.1.1.3. Groundwater

Surficial materials at the 881 Hillside Site consist of Rocky Flats Alluvium, colluvium, and valley fill alluvium. The Rocky Flats Alluvium beneath the land surface (at and north of Building 881) varies in thickness from about 4 to 14 ft. The Rocky Flats Alluvium is a poorly sorted deposit of sand, gravel, and cobbles that contains some clay horizons. The 881 hillside itself is mantled with slopewash material (colluvium) consisting of sandy clay (2 to 5 ft thick) underlain by 4 to 5 ft of sandy gravel. The materials underlying the slope merge downhill with the valley fill alluvium. The valley fill alluvium consists of thin (3 to 8 ft thick) sandy gravels. Bedrock beneath the 881 hillside consists of approximately 10 ft of claystone underlain by 7 to 12 ft of sandstone. The sandstone is in turn underlain by more claystone. These Arapahoe Formation claystones and sandstones dip approximately 15 to 30° to the east (DOE 1986f).

The hydrogeology of the 881 hillside appears to be dominated by flow from the Rocky Flats Alluvium, through the colluvium, and into the valley fill alluvium. The flow system is complicated by apparently unsaturated portions of the Rocky Flats Alluvium both west and east of Building 881. Groundwater occurs in the sandy gravel of the slopewash material (saturated thickness of about 1.5 ft) and in the sandstone bedrock. The static water level in the sandstone appears to be about 18 ft lower than in the slopewash.

Results of groundwater sampling (DOE 1986f) indicate that groundwater in both bedrock and surficial materials is of poorer quality than upgradient groundwater in the Rocky Flats Alluvium. The waters at the 881 hillside generally contain more sodium (as a percentage of major ions) than upgradient alluvial waters and have total dissolved solids (TDS) in the range of 1000 milligrams per liter (mg/l). Upgradient alluvial groundwaters have TDS concentrations of approximately 100 to 200 mg/l. Radioactive constituent values are approximately equal to upgradient values, and dissolved metal concentrations are generally similar. However, strontium concentrations are considerably higher at the 881 hillside than at upgradient locations. Volatile organic compounds (VOCs) were detected in only one area of the 881 hillside (bedrock well 9-74, IGMP/CSPCP Sampling Plan, Plate 2). Significant concentrations (greater than 1000 ppb) of 1,1-dichloroethylene (1,1 DCE), 1,1,1-trichloroethane (1,1,1 TCA), trichloroethylene (TCE), and tetrachloroethylene (PCE) were found.

3.1.2. Source Characterization

3.1.2.1 Health and Safety Screening

Prior to any surveying or sampling activities at the 881 Hillside Site, a screening for radioactive and chemical contaminants will be conducted. Radiation screening will be performed using a field instrument for detection of low energy radiation (FIDLER), and chemical screening will be done with a photoionization detector (PID). If significant surficial contamination is detected during screening, detailed health and safety surveys will be performed. Detailed surveys will consist of FIDLER and PID readings at each survey grid node as described in Section 3.1.2.2.

3.1.2.2. Survey Grid

A 30-ft centered grid will be established for implementation of geophysical and soil gas surveys. Grid node locations will be surveyed to an accuracy of 1 ft. Plate 2 shows the location and possible extent of this grid.

3.1.2.3. Surface Geophysics

Several types of surface geophysics will be performed at the 881 Hillside Site to identify and delineate source areas. Each of these methods is discussed below. Specific procedures and equipment specifications for these techniques are presented in Appendixes A and B of the IGMP/CSPCP Sampling Plan.

Electromagnetics. An electromagnetic induction survey will be performed over portions of the area shown on Plate 2 with an EM 34-3 and EM 31 terrain-conductivity instruments manufactured by Geonics Ltd. The EM 34-3 survey will be performed at a 20-m coil spacing with horizontal dipoles yielding an effective exploration depth of about 50 ft for source identification. Measurements will be taken on 60-ft centers within the survey grid. The EM 31 survey will be performed for more detailed source identification. The EM 31 survey will be conducted at 15-ft centers in a continuous recording mode within the survey grid.

The instrument readings of terrain conductivity in millimhos per meter (mmhos/m) will be plotted by location on a base map and values of terrain conductivity contoured to identify areas of increased or decreased conductivity relative to background values. The anomalous areas should be indicative of source areas.

<u>Magnetometer</u>. A magnetometer survey will be conducted to screen the area for buried metallic objects. The magnetometer survey will be performed over the same area as the electromagnetic induction survey using a portable proton memory magnetometer/gradiometer manufactured by EG&G Geometrics. Measurements will be collected at 15-ft centers across the gridded area. Also, closely spaced measurements will be collected along the edges of anomalous areas for boundary definition.

Magnetometer readings in gammas will be plotted within the grid and computer contoured to highlight areas of significant magnetic anomaly. These areas should indicate the presence of buried metallic objects.

<u>Metal Detection</u>. Subsequent to the evaluation of the magnetometer and electromagnetic data, a detailed metal detection survey will be performed at selected magnetic and/or electromagnetic induction anomalies using a White's Model TM 600 S2. The objective of this effort is to precisely locate buried drums. These locations will be red-flagged to prevent drilling through the drums during the soil sampling program.

<u>Electrical Resistivity Soundings</u>. Vertical electrical resistivity soundings will be performed at the 881 Hillside Site to develop data on the vertical extent of the source areas. Approximately 20 vertical electrical soundings will be performed at the 881 Hillside Site. The locations of these soundings will be selected subsequent to the review of electromagnetic induction and magnetometer data. A Bison Instruments BOSS Model 2365 resistivity sounding system will be used to perform the resistivity soundings. The soundings will be performed to an effective depth of approximately 50 ft.

The resistivity data will be assessed in the form of depth versus resistivity plots, and the locations of interfaces indicating changes in resistivity values will be identified. These interfaces should indicate the depth of the source area, depth to the water table, and depth to the bedrock.

3.1.2.4. Soil Gas Surveys

A soil gas survey will be carried out at the 881 Hillside Site to identify and confirm the locations of the solid waste management units and, if possible, to rank these solid waste management units according to their priority within the site. The soil gas survey will serve to characterize both the sources and aerial extent of plumes on the 881 hillside. The survey lines will run perpendicular to anticipated flow patterns (Plate 2). Soil gas samples will be collected on 90-ft centers following the procedures in Appendix A of the IGMP/CSPCP Sampling Plan. Based on the results of these data, additional soil gas samples will be collected near sources to determine the boundaries of the solid waste management units.

3.1.2.5. Soil/Waste Sampling

The contents (soils and wastes) of solid waste management units within the 881 Hillside Site will be sampled after the geophysical and soil gas surveys are completed. Specific sampling locations will be defined based on geophysical and soil gas survey results; however, each unit will contain at least two sampling locations (Plate 3). At this time, it is anticipated that soil/waste sampling will consist of

- two borings in the oil sludge pit and chemical burial units,
- two borings in the liquid dumping unit,
- three borings in the vicinity of the outfall and hillside oil leak units,
- five borings in the multiple solvent spill area (three borings in the west area and two borings in the east area), and
- five borings in the radioactive site #1 unit.

Samples will be analyzed for the parameters listed in Table 3.1.

3.1.3. Migration Pathway and Plume Characterization

3.1.3.1. Soil Gas Surveys

The soil gas survey conducted at the 881 Hillside Site for source characterization will also serve to detect and quantify the extent of any volatile organic groundwater plumes. Soil gas samples will be collected on 90-ft centers along the survey lines shown on Plate 2. If a plume is detected, the soil gas survey will be expanded to delineate the plume.

3.1.3.2. Soil Sampling

In addition to soil/waste sampling at the 881 Hillside Site, soil sampling may be performed to delineate the extent of soil contamination and to characterize migration pathways. Specific sampling locations will be determined after completion of the soil gas survey. Samples will be collected from boreholes and monitoring well installations, as described in Appendix A of the IGMP/CSPCP Sampling Plan and analyzed for the parameters listed in Table 3.1.

3.1.3.3. Monitor Well Installation and Groundwater Sampling

Results of the geophysical and soil gas surveys will be used to determine the exact number and locations of monitor wells on the 881 hillside. At this time, eight new monitor wells are anticipated (Plate 4). One of the new wells will be an upgradient alluvial well, probably located west of existing wells 59-86 and 69-86, and another will be a bedrock well at the location of 60-86. A well pair (one alluvial and one bedrock) will be completed south of the fuel oil spills (SWMU Ref. Nos. 106 and 107), and two additional well pairs will be completed south (downgradient) of the radioactive material disposal (SWMU Ref. No. 130) and multiple solvent spill areas (SWMU Ref. Nos. 119.1 and 119.2).

There are currently five monitor wells in the vicinity of the 881 Hillside Site. Well 61-86 is located upgradient of the site and is completed in Rocky Flats Alluvium. Wells 10-74 and 59-86 are located downgradient of the site and are completed in colluvium. Wells 9-74 and 69-86 are downgradient bedrock monitor wells. These wells will be sampled at the same time newly installed wells are sampled.

Groundwater samples will be collected from new and existing wells at the 881 Hillside Site following the procedures in Appendix A of the IGMP/CSPCP Sampling Plan. Samples will be analyzed for the parameters listed in Table 3.2. Based on results of soil/waste sampling performed during source characterization, this parameter list may be modified to include additional contaminants.

3.1.3.4. Surface Water and Sediment Sampling

Surface water samples will be collected from established sampling locations upstream and downstream from the 881 Hillside Site (IGMP/CSPCP Sampling Plan, Plate 2). Included will be stations along the South Interceptor Ditch and Woman Creek. Surface water samples will also be collected from the outfall (SWMU Ref. No. 106) and any other springs or seeps occurring on the hillside. Additional surface water and/or sediment samples may be collected, depending on soil gas survey results. Samples will be analyzed for the parameters in Tables 3.1 and 3.2 as appropriate.

- 903 Lip Area (SWMU Ref. No. 155) - During drum removal and cleanup of the 903 drum storage area, winds redistributed plutonium beyond the pad to the south and east. The area was partially cleaned in 1976 and 1978 when about 4.7 million pounds of contaminated soil containing 0.56 Ci of plutonium was packaged and shipped to an off-site DOE disposal facility. Additional cleanup was performed along the eastern edge of the 903 Lip Area in 1984.

- Gas Detoxification Area (SWMU Ref. No. 183) - Building 952, located south of the 903 drum storage area, was used to detoxify various gases from leture bottles between June 1982 and August 1983. The lecture bottles held approximately one liter of compressed gas. Various gases were detoxified using commercial neutralization processes. After neutralization, glassware used in the process was triple-rinsed, crushed, and deposited in the present landfill. The neutralized gases released to the environment during detoxification would no longer be detectable.

3.2.1.2. Surface Water

Surface water drains toward the north, east, and south from the 903 pad area. The north- and east-flowing water enters Central Avenue ditch and then South Woman Creek (above the retention ponds). The south-flowing surface water runs down the slope toward Woman Creek but enters the South Interceptor Ditch and is diverted to the retention pond.

3.2.1.3. Groundwater

The 903 pad is underlain by about 4 to 20 ft of Rocky Flats Alluvium. The slope to the south, which is also included in the 903 pad area, is underlain by 15 to 22 ft of colluvium. The colluvium consists primarily of silty clay with a trace of gravel and contains discrete gravel layers (possibly lenses) from 1 to 4 ft thick. The valley fill, with which the colluvium merges to the south (downhill), consists of 3 to 8 ft of sandy gravel. Bedrock beneath the slope consists of interbedded claystones and sandstones of the Arapahoe Formation. The uppermost bedrock is claystone and the interbedded sandstones are on the order of 2 to 10 ft thick.

The Rocky Flats Alluvium and colluvial materials on the slope toward Woman Creek appear to be unsaturated at the 903 Pad Area Site. The uppermost groundwater occurs in bedrock (at least during the winter months) at a depth of approximately 10 to 25 ft below ground surface beneath the center of the slope.

The results of groundwater sampling described by DOE (1986f) indicate highly variable groundwater quality conditions beneath the 903 Pad Area Site. Data indicate that groundwater at this site has elevated TDS, sodium, radionuclides (plutonium and uranium), volatile organic compounds, and nitrates.

3.2.2. Source Characterization

3.2.2.1. Health and Safety Screening

Prior to any surveying or sampling activities at the 903 Pad Area Site, a screening for radioactive and chemical contaminants will be conducted. Radiation screening will be performed using a field instrument for detection of low energy radiation (FIDLER), and chemical screening will be done with a photoionization detector (PID). If significant surficial contamination is detected during screening, detailed health and safety surveys will be performed. Detailed surveys will consist of FIDLER and PID readings at each survey grid node as described in Section 3.2.2.2.

3.2.2.2. Survey Grid

A 30-ft centered grid will be established at the 903 Pad Area Site as the basis for site surveys and sampling (Plate 2). Grid node locations will be surveyed to an accuracy of 1 ft.

3.2.2.3. Surface Geophysics

Several types of geophysical surveys will be performed at the 903 Pad Area Site to identify and delineate source areas. Each of these methods is discussed below. Specific procedures and equipment specifications for these techniques are presented in Appendixes A and B of the IGMP/CSPCP Sampling Plan.

Electromagnetics. An electromagnetic induction survey of the 903 pad area will delineate the location of trenches within the site and the overall extent of waste disposal. The electromagnetic induction survey will be performed with EM 34-3 and EM 31 terrain-conductivity survey meters. The EM 34-3 meter will be used in the horizontal and vertical dipole modes at a 20-m coil spacing for an effective survey depth of approximately 50 ft. Measurements will be made at 60-ft centers within the survey grid. The EM 31 survey will be conducted at 15-ft centers in a continuous mode within the survey grid. Also, closely spaced measurements will be made along the edges of anomalous areas for boundary definition.

The electromagnetic data will be plotted and contoured. The results will be in the form of a contour map indicating areas of anomalous conductivity.

Magnetometer. A magnetometer survey will be performed at the 903 Pad Area Site to identify areas containing buried metallic objects, including drums. Magnetometer readings will be collected at 15-ft centers within the survey grid. Closely spaced measurements will be collected along the edges of anomalous areas for boundary definition. The data will be plotted, contoured, and evaluated to indicate areas of magnetic anomalies.

Metal Detection. A detailed survey of the magnetic anomalies will be performed using a White's metal detector to precisely locate those areas where buried drums are suspected. These locations will be flagged to prevent potential drum puncture during the soil sampling program.

Electrical Resistivity Soundings. Vertical electrical soundings will be conducted at approximately 10 locations within the 903 Pad Area Site. These locations will be selected based on electromagnetic and magnetometer survey results. The soundings will provide a vertical profile of resistivity, which should indicate the depth of waste disposal, water table, and bedrock. The soundings will be made to an effective depth of about 50 ft.

3.2.2.4. Soil Gas Surveys

A soil gas survey will be carried out at the 903 Pad Area Site to identify and confirm the locations of the solid waste management units and, if possible, to rank these solid waste management units according to their priority within the site. The soil gas survey will serve to characterize both the sources and plumes at the 903 pad area and will consist of survey lines running perpendicular to flow (Plate 2). Soil gas samples will be collected on 90-ft centers following the procedures in Appendix A of the IGMP/CSPCP Sampling Plan. Based on the results of these data, additional soil gas samples will be collected near sources to determine the boundaries of the solid waste management units.

3.2.2.5. Soil/Waste Sampling

In order to characterize the sources at the 903 Pad Area Site, soil and wastes beneath the 903 pad and on the hillside below will be sampled during CEARP Phase 2 (Plate 3). Precise sampling locations will be defined based on geophysical and soil gas survey results. However, it is anticipated that soil/waste sampling will consist of

- four borings through the 903 pad to characterize subsurface materials,
- five borings in the 903 lip area (three borings in the main lip area and two borings in the wind dispersal area to the east and west),
- two borings adjacent to or through Trench T-2 to characterize its contents and and the materials below it, and
- three borings in the reactive metal destruction site to characterize its contents.

Samples will be analyzed for the parameters listed in Table 3.1.

3.2.3. Migration Pathways and Plume Characterization

3.2.3.1. Soil Gas Surveys

The soil gas survey conducted at the 903 Pad Area Site for source characterization will also serve to detect and quantify the extent of any volatile organic groundwater plumes. Soil gas samples will be collected on 90-ft centers along the survey lines shown on Plate 2 at the same time as the source characterization soil gas sampling. If a plume is detected, the soil gas survey will be expanded to delineate the plume.

3.2.3.2. Soil Sampling

Soil sampling may be performed to delineate the extent of soil contamination and to characterize migration pathways at the 903 Pad Area Site. Specific sampling locations will be based on the soil gas survey results. Samples will be collected from boreholes and monitoring well installations, as described in Appendix A of the IGMP/CSPCP Sampling Plan and analyzed for the parameters listed in Table 3.1.

3.2.3.3. Monitor Well Installation and Groundwater Sampling

Geophysical and soil gas survey results will be used to determine the exact number and locations of monitor wells at the 903 Pad Area Site. Approximately eight new monitor wells are currently anticipated (Plate 4). These wells will probably include

- a well pair west of the 903 pad to characterize upgradient groundwater flow and quality,
- a well pair east of the 903 pad to further evaluate groundwater flow in this area
- a well pair south of trench T-2 to track downgradient groundwater plumes, and
- a well pair east of the perimeter road and north of pond C-1 to characterize downgradient groundwater quality in that direction.

Existing well 65-86 in the drainage of Woman Creek will be sampled at the same time the newly installed wells are sampled.

Groundwater samples will be collected from new and existing wells at the 903 Pad Area Site following the procedures in Appendix A of the IGMP/CSPCP Sampling Plan. Samples will be analyzed for the parameters listed in Table 3.2. Based on results of soil/waste sampling performed during source characterization, this parameter list may be modified to include additional contaminants.

3.2.3.4. Surface Water and Sediment Sampling

Surface water samples will be collected from established sampling locations upstream and downstream of the 903 Pad Area Site (IGMP/CSPCP Sample Plan, Plate 2). Included will be stations along the South Interceptor Ditch, Woman Creek, and Pond C-1. Surface water samples will also be collected from any springs or seeps occurring on the hillside below the pad. Additional surface water and/or sediment samples may be collected, depending on soil gas survey results. Samples will be analyzed for the parameters in Tables 3.1 and 3.2 as appropriate.

3.3. MOUND AREA SITE

3.3.1. Site Description

3.3.1.1. Solid Waste Management Unit Descriptions

The Mound Area Site is composed of four solid waste management units (SWMUs) as described below.

- Trench T-1 (Ref. No. 108) - Trench T-1 is located just north of Central Avenue and immediately west of the old East Guard Gate (Gate 9). It was used from 1952 to 1962 and contains 125 drums filled with depleted uranium chips coated with small amounts of lathe coolant. The trench was covered with 2 ft of soil and the corners marked; however, two drums were uncovered during weed cutting operations in 1982. The contents of one of the drums were tested and found to contain an oily sludge with 4.3 picocuries per gram of plutonium and 1.2 microcuries per gram of uranium.

- Mound Area (SWMU Ref. No. 113) - The mound area is located north of Central Avenue and west of the East Guard Gate. From 1954 to 1958, 1405 drums filled with depleted uranium and beryllium wastes were buried in the mound area. The wastes were mostly solid; however, some of the drums contained lathe coolant. The drums were removed between 1967 and 1970 and shipped offsite as radioactive waste. Although residual radioactive contamination may be present in the soils (0.8 to 112.5 dpm/g alpha activity), the contamination is thought to have come from the 903 drum storage area.

- Oil Burn Pit Number 2 (Ref. No. 153) - Oil Burn Pit Number 2, west of the mound area, was used in 1957 and from 1961 to 1965 to burn approximately 1083 drums of oil containing uranium. The residues from the burning operations and some flattened drums were covered with soil. In 1978, the pit was excavated to a depth of approximately 5 ft and 239 boxes of contaminated material were removed and shipped offsite to a DOE disposal facility.

- Pallet Burn Site (Ref. No. 154) - In 1965, an area southwest of oil burn pit number 2 was reportedly used to destroy wooden pallets. The nature of contamination, if any, of the pallets is not known. Residues from the operation were removed in the 1970s.

3.3.1.2. Surface Water

Surface water flow in the vicinity of the Mound Area Site is dominated by the Central Avenue ditch which crosses the plant site, flowing to the east. All water then flows northward toward South Walnut Creek. Runoff from the mound area finally enters the retention ponds in South Walnut Creek (B series ponds).

3.3.1.3. Groundwater

All solid waste management units included in the Mound Area Site are located on the Rocky Flats surface and are underlain by as much as 16 ft of Rocky Flats Alluvium. The alluvium consists of 11 ft of fine to medium sand on top of 5 ft of sandy gravel. Bedrock beneath the alluvium consists of interbedded claystone and sandstone of the Arapahoe Formation. Uppermost bedrock is claystone (1.5 ft thick) underlain by thin interbedded sandstones and claystones.

Groundwater occurs in bedrock at about 18 ft below ground surface. The alluvium is unsaturated. Flow in the bedrock is probably both north (along strike--toward the topographically lower drainage) and east (down dip).

Bedrock groundwater quality in the vicinity of the Mound Area Site is characterized by the presence of volatile organic compounds. The groundwater sampling results presented by DOE (1986f) indicate that major ion chemistry in bedrock groundwater at the Mound Area Site is slightly different from alluvial groundwater upgradient of the plant. However, this groundwater has low concentrations of radioactive constituents (at background or lower) and has generally nondetectable metals.

3.3.2. Source Characterization

3.3.2.1. Health and Safety Screening

Prior to any surveying or sampling activities at the Mound Area Site, a screening for radioactive and chemical contaminants will be conducted. Radiation screening will be performed with a field instrument for detection of low-energy radiation (FIDLER) and chemical screening will be done with a photoionization detector (PID). If significant surficial contamination is detected during screening, detailed health and safety surveys will be performed. Detailed surveys will consist of FIDLER and PID readings at each survey grid node as described in Section 3.3.2.2.

3.3.2.2. Survey Grid

A 30-ft centered grid will be established at the Mound Area Site as the basis for site surveys and sampling. Grid node locations will be surveyed to an accuracy of 1 ft.

3.3.2.3. Surface Geophysics

Several types of geophysical surveys will be performed at the Mound Area Site to identify and delineate source areas. Each of these methods is discussed below. Specific procedures and equipment specifications for these techniques are presented in Appendixes A and B of the IGMP/CSPCP Sampling Plan.

Electromagnetics. An electromagnetic induction survey of the Mound Area Site will be performed to determine the aerial extent of soil contamination. The survey will be performed with an EM 34-3 terrain-conductivity meter used in the horizontal and vertical dipole positions with intercoil spacing of 20 m. This configuration yields an effective exploration depth of approximately 50 ft. Measurements will be taken on 60-ft centers within the surveyed grid at the Mound Area Site. An EM 31 terrain conductivity meter survey will be performed on approximately 10-ft centers along the edges of anomalous areas for boundary definition. Conductivity measurements will be plotted and contoured to locate areas of increased or decreased conductivity as compared to background levels.

Magnetometer. A magnetometer survey using a portable proton magnetometer will be performed to complement the electromagnetic survey. The magnetometer survey will identify areas that may contain buried metallic objects, including drums. Magnetometer measurements will be taken on approximately 10-ft centers along the edges of anomalous areas for boundary definition.

The magnetometer data will be plotted and contoured to indicate areas of high magnetic susceptibility. These areas indicate the possible presence of buried metallic objects.

Metal Detection. Areas that are found to contain metallic objects (from electromagnetic induction and magnetometer data) will be further investigated using a White's TM 60 S2 metal detector. The metal detection survey will precisely locate buried metallic objects, minimizing the potential for drum puncture during the soil investigation.

Electrical Resistivity Soundings. Approximately six vertical resistivity soundings will be conducted at the Mound Area Site to determine the approximate depth of the source areas. A Bison Instrument Model 2365 resistivity instrument will be used to perform the resistivity soundings. The soundings will provide a vertical profile of resistivity, which should indicate the depth of waste disposal, water table, and bedrock.

3.3.2.4. Soil Gas Surveys

A soil gas survey will be used at the Mound Area Site to identify and confirm the locations of the solid waste management units and, if possible, to rank these solid waste management units according to their priority within the site. The soil gas survey will serve to characterize both the sources and plumes at the Mound Area Site and will consist of survey lines running perpendicular to flow. Soil gas samples will be collected on 90-ft centers following the procedures in Appendix A of the IGMP/CSPCP Sampling Plan. Based on the results of these data, additional soil gas samples will be collected near sources to determine the boundaries of the solid waste management units.

3.3.2.5. Soil/Waste Sampling

In order to characterize sources at the Mound Area Site, soils and wastes in each solid waste management unit at the site will be sampled during CEARP Phase 2 (Plate 3). Specific sampling locations will be defined according to geophysical and soil gas survey results. However, it is anticipated that soil/waste sampling will consist of

- two borings in the mound area to identify any residual contaminants,
- two borings through or adjacent to Trench T-1 to characterize its contents, and
- two borings through the oil burn pit and the pallet burn site to identify potential contaminants.

Samples will be analyzed for the parameters listed in Table 3.1.

3.3.3. Migration Pathway and Plume Characterization

3.3.3.1. Soil Gas Surveys

The soil gas survey conducted at the Mound Area Site for source characterization will also serve to detect and quantify the extent of any volatile organic groundwater plumes. Soil gas samples will be collected on 90-ft centers (Plate 2) at the same time that the source characterization soil gas sampling is taking place. If a plume is detected, the soil gas survey will be expanded to delineate the plume.

3.3.3.2. Soil Sampling

Soil sampling may be performed to delineate the extent of soil contamination and to characterize migration pathways at the Mound Area Site. Specific sampling locations will be based on the soil gas survey results. Samples will be collected from boreholes and monitoring well installations, as described in Appendix A of the IGMP/CSPCP Sampling Plan and analyzed for the parameters listed in Table 3.1.

3.3.3.3. Monitor Well Installation and Groundwater Sampling

Geophysical and soil gas survey results will be used to determine the exact number and locations of monitor wells at the Mound Area Site. Approximately six new monitor wells (three well pairs) are currently anticipated (Plate 4). These wells will probably include a well pair north of the mound area, a well pair east of Trench T-1, and a well pair northwest of the mound area and oil burn pit.

Existing well 43-86 will be used to characterize upgradient alluvial groundwater quality.

Groundwater samples will be collected from new and existing wells at the Mound Area Site following the procedures in Appendix A of the IGMP/CSPCP Sampling Plan. Samples will be analyzed for the parameters listed in Table 3.2. Based on results of soil/waste sampling performed during source characterization, this parameter list may be modified to include additional contaminants.

3.3.3.4. Surface Water and Sediment Sampling

Surface water samples will be collected from established sampling locations upstream and downstream from the Mound Area Site. Included will be stations along the Central Avenue Ditch and South Walnut Creek. Surface water samples will also be collected from any springs or seeps occurring on the hillside north of the mound area. Additional surface water and/or sediment samples may be collected based on soil gas survey results. Samples will be analyzed for the parameters in Tables 3.1 and 3.2 as appropriate.

3.4. EAST TRENCHES SITE

3.4.1. Site Description

3.4.1.1. Solid Waste Management Unit Descriptions

The East Trenches Site consists of nine burial trenches (Trenches T-3 through T-11) located just east of the East Access Gate. The trenches were used from 1954 to 1968 for disposal of depleted uranium, flattened depleted uranium and plutonium contaminated drums, and sanitary sewage sludge. The trenches are approximately 50 x 300 ft each. Trench T-3 (SWMU Ref. No. 110) received radioactively contaminated flattened drums and substantial quantities of sanitary sewage sludge. The drums placed in Trenches T-4 through T-11 (SWMU Ref. No. 111) had radioactivity ranging from 800 to 8000 dpm/g. Trenches T-4 and T-11 also contain some uranium and plutonium contaminated planks from the solar evaporation ponds and sanitary sewage sludge. The trenches are covered with soil.

3.4.1.2. Surface Water

Surface water in the vicinity of the East Trenches Site flows both to the north (South Walnut Creek) and to the south (Woman Creek). Flows in the immediate area on top of the terrace are primarily sheet flow until they become concentrated by various ditches (extension of Central Avenue ditch to the north and access road ditches to the south). Flows which enter the Central Avenue ditch are carried to the retention pond system in South Walnut Creek (B-series). Flows which enter either of the access road ditches leave the site, flowing either to Walnut or Woman Creek below the retention ponds. Flows to the south off the terrace are apparently not concentrated artificial ditches and enter the Woman Creek drainage both upstream and downstream from the retention ponds.

3.4.1.3. Groundwater

The East Trench site is underlain by variable but relatively thick Rocky Flats Alluvium (approximately 28 to 45 ft thick). The alluvium is predominately sandy gravel with a few thin (2 to 3 ft thick) sand layers and thin (2 to 4 ft thick) clay layers. Bedrock consists of claystones and sandstones of the Arapahoe Formation. Both claystone and sandstone were found immediately beneath the alluvium in the vicinity of the trenches. Sandstones encountered in drilling well 40-86 were thicker than those encountered elsewhere at the plant (21 ft thick).

Groundwater occurs in both alluvium and bedrock. The depth to groundwater in the alluvium is approximately 20 to 25 ft below the ground surface. Much of the recharge to the alluvial system is probably from irrigation because the Rocky Flats Alluvium is unsaturated west of the trench area. Natural groundwater flow is in three directions: north toward South Walnut Creek, east towards the Plant boundary, and south toward Woman Creek. There is a large spring on the south-facing slope between the terrace and Woman Creek that is fed by eastern and southern flows from the trench area. Depth to water in the bedrock is unknown, but based on data collected from installation of well 40-86, there appears to be a substantial downward gradient between the alluvium and the bedrock.

Groundwater quality is characterized by the presence of volatile organic compounds. TDS concentrations are slightly elevated and radioactive constituent concentrations are roughly equal to those in upgradient alluvial groundwater. However, volatile organic compounds were detected in three of the four wells near the trenches. Specific information on the quality of groundwater in the bedrock is not available.

3.4.2. <u>Source Characterization</u>

3.4.2.1. Health and Safety Screening

Prior to any surveying or sampling activities at the East Trenches Site, a screening for radioactive and chemical contaminants will be conducted at each area to be investigated. Radiation screening will be performed with field instruments for detection of low-energy radiation (FIDLER), and chemical screening will be done with a photoionization detector (PID). If significant surficial contamination is detected during screening, detailed health and safety surveys will be performed. Detailed surveys will consist of FIFLER and PID readings at each survey grid node as described in Section 3.4.2.2.

3.4.2.2. Survey Grid

A 30-ft centered grid will be established at the East Trenches Site as the basis for site surveys and sampling. Grid node locations will be surveyed to an accuracy of 1 ft.

3.4.2.3. Surface Geophysics

Several types of geophysical surveys will be performed at the East Trenches Site to identify and delineate source areas. Each of these methods is discussed below. Specific procedures and equipment specifications for these techniques are presented in Appendixes A and B of the IGMP/CSPCP Sampling Plan.

<u>Magnetometer</u>. A magnetometer survey will be performed over each trench to determine the general locations of buried metallic objects and/or drums. A portable proton magnetometer manufactured by EG&G Geometrics will be used to measure variations in the earth's magnetic field created by materials of high magnetic susceptibility. Magnetometer readings will be collected on 10-ft centers across the trenches within the surveyed grid. The resulting data will be plotted and contoured to indicate areas of high magnetic susceptibility.

<u>Metal Detection</u>. A metal detector will be used as a follow-up to the magnetometer survey to precisely locate buried metallic objects. Buried metallic objects will be flagged so no drums will be punctured during the soil-boring program.

<u>Electrical Resistivity Soundings</u>. Two vertical electric resistivity soundings will be performed at each trench for a total of 18 soundings to determine the depths of the trenches. The resistivity sounding will be performed using a Bison Model 2365 resistivity meter with the BOSS cable system. The resistivity data will be evaluated and the depth of electrical interfaces will be identified to indicate depth of trench, depth to groundwater, and depth to bedrock. The effective depth of the resistivity survey will be approximately 50 ft.

3.4.2.4. Soil Gas Surveys

A soil gas survey will not be used at the East Trenches Site for source characterization. Section 3.4.3.1. discusses plume delineation with soil gas at the east trenches.

3.4.2.5. Soil/Waste Sampling

In order to characterize the sources at the East Trenches Site, the contents of each trench (T-3 through T-11) may be sampled. Specific sampling locations will be defined according to geophysical survey results; however, at least two borings will be drilled into each trench or adjacent to each trench (one at each end) (Plate 3).

Samples will be analyzed for the parameters listed in Table 3.1.

3.4.3. <u>Migration Pathway and Plume Characterization</u>

3.4.3.1. Soil Gas Surveys

The soil gas survey conducted at the East Trenches Site will serve to detect and quantify the extent of any volatile organic groundwater plumes. Soil gas samples will be collected on 90-ft centers (Plate 2) following procedures in Appendix A of the IGMP/CSPCP Sampling Plan. If a plume is detected, the soil gas survey will be expanded to delineate the plume.

3.4.3.2. Soil Sampling

Soil sampling may be performed to delineate the extent of soil contamination and to characterize migration pathways at the East Trenches Site. Specific sampling locations will be based on the soil gas survey results. Samples will be collected from boreholes and monitoring well installations, as described in Appendix A of the IGMP/CSPCP Sampling Plan and analyzed for the parameters listed in Table 3.1.

3.4.3.3. Monitor Well Installation and Groundwater Sampling

Geophysical and soil gas survey results will be used to determine the exact number and locations of monitor wells at the East Trenches Site. Thirteen new monitor wells are currently anticipated (Plate 4). This monitoring system will likely consist of

- a well pair west of Trench T-3 to characterize upgradient alluvial water quality,
- a well pair north of Trenches T-3 and T-4 to determine downgradient water quality north of the East Trenches Site,
- two well pairs south and southeast, respectively, of Trenches T-5 through T-8 to characterize groundwater flow off the terrace,
- an alluvial well south of the east access road and Trench T-10 to characterize alluvial groundwater flow east of Trench T-5 through T-9,
- a well pair north of Trench T-5 to characterize downgradient groundwater quality east of Trenches T-3, T-4, T-10 and T-11, and
- a well pair south of the East Trenches Site on the Slocum Alluvium terrace below the Rocky Flats surface to define the downgradient extent of groundwater contamination south of the site.

Existing wells 40-86, 41-86, 42-86 and 7-74 will also be used to further evaluate the groundwater flow systems and groundwater quality at the East Trenches Site.

Groundwater samples will be collected from new and existing wells at the East Trenches Site following the procedures in Appendix A of the IGMP/CSPCP Sampling Plan. Samples will be analyzed for the parameters listed in Table 3.2. Based on results of soil/waste sampling performed during source characterization, this parameter list may be modified to include additional contaminants.

3.4.3.4. Surface Water and Sediment Sampling

Surface water samples will be collected from established sampling locations upstream and downstream from the East Trenches Site. Included will be stations along the Central Avenue Ditch, the South Interceptor Ditch, South Walnut Creek and Woman Creek. Surface water samples will also be collected from any springs or seeps occurring on the hillsides north or south of the east trenches. Additional surface water and/or sediment samples may be collected based on soil gas survey results. Samples will be analyzed for the parameters in Tables 3.1 and 3.2 as appropriate.

3.5. PRESENT LANDFILL SITE

3.5.1. Site Description

3.5.1.1. Solid Waste Management Unit Descriptions

The Present Landfill Site consists of the present landfill and two other solid waste management units on the hillsides east of the landfill as discussed below.

- The Present Landfill (SWMU Ref. No. 114) - The present landfill is located north of the main plant area at the head of an tributary to North Walnut Creek. The existing portion of the present landfill will be closed to meet the performance standards of 40 CFR 265.11 (DOE 1986a).

  Operations at the present landfill began in August 1968 on a fill placed across the drainage using on-site soils. Based on engineering studies performed by consultants, collection systems for groundwater, surface water, and leachate were installed in 1974, together with two downstream impoundments to hold the various fluids. In 1978 and 1979, the Colorado Department of Health inspected the landfill and found it to be in compliance with State regulations. Between 1977 and 1981, the leachate collection system was buried by landfill expansion. However, the groundwater control structure was extended beyond the expanded landfill by the installation of slurry walls in 1981. Also in 1981, one of the impoundments was removed to allow further landfill expansion.

  Operational procedures have evolved over the life of the landfill. In July 1977, a solid waste management plan was prepared that excluded radioactive wastes and allowed liquid wastes only with a special permit from the Waste Management and Hazardous Materials Committee of Rockwell International.

Most of the 20 to 30 cubic yards of waste delivered to the landfill each day is office trash; however, a certain amount of construction debris and shop wastes are included. Small quantities of hazardous materials including solvents and paints have been incorporated into the landfill with the construction debris and shop wastes. In addition, it is possible that prior to initiation of radiometric monitoring in 1973, a certain amount of radioactive material may also have been incorporated into the fill.

- Trenches (Ref. No. 166) - Three trenches were operated in the vicinity of the landfill for disposal of sanitary sewer sludge contaminated with uranium and possibly plutonium.

- Spray Fields (Ref. No. 167) - Three areas are used for spray irrigation of landfill pond water in order to enhance evaporation. Spraying began sometime after 1968 and has continued to the present.

3.5.1.2. Surface Water

Surface water in the vicinity of the present landfill site generally flows to the east on the terrace. Most of the runoff enters the landfill pond and is disposed of by natural and enhanced evaporation. Enhanced evaporation consists of spray irrigating the slope south of the pond. Flow patterns are controlled by the ditches that circle the landfill and by the presence of the various roads. The Church and McKay ditches and the North Walnut Creek diversion ditch cross the terrace surface north of the landfill.

3.5.1.3. Groundwater

Most of the area in the vicinity of the present landfill is underlain by about 22 to 23 ft of Rocky Flats Alluvium. The alluvium was found to contain discrete layers of sand (7 ft thick) and of silt (4 ft thick). Bedrock immediately beneath the alluvium is Arapahoe Formation claystone. In well 9-86, located west of the landfill, 100 ft of claystone and siltstone were penetrated before sandstone.

Groundwater occurs in the vicinity of the present landfill in both the Rocky Flats Alluvium and the Arapahoe Formation bedrock. The general direction of groundwater flow in the alluvium is toward the east with some flow toward the south-east near the North Walnut Creek drainage. Depth to groundwater in the Rocky Flats Alluvium is approximately 10 ft below ground surface. In the drainage downgradient of the landfill, the valley fill material is dry, indicating that the water control systems at the landfill are probably functioning as designed.

Limited data are available relative to groundwater quality conditions at the present landfill. All downgradient wells, with the exception of Well WS-2, were dry. At Well WS-2, sufficient sample was only available for HSL volatiles analysis. No volatiles were detected.

3.5.2. Source Characterization

3.5.2.1. Health and Safety Screening

Prior to any surveying or sampling activities at the 881 Hillside Site, a screening for radioactive and chemical contaminants will be conducted. Radiation screening will be performed using a field instrument for detection of low energy radiation (FIDLER), and chemical screening will be done with a photoionization detector (PID). If significant surficial contamination is detected during screening, detailed health and safety surveys will be performed. Detailed surveys will consist of FIDLER and PID readings at each survey grid node as described in Section 3.5.2.2.

3.5.2.2. Survey Grid

A 30-ft centered grid will be established for implementation of geophysical and soil gas surveys. Grid node locations will be surveyed to an accuracy of 1 ft. Plate 2 shows the location and extent of this grid.

3.5.2.3. Surface Geophysics

Several types of geophysical surveys will be performed at the Present Landfill Site to delineate burial trenches east of the landfill. Each of these methods is discussed below. Specific procedures and equipment specifications for these techniques are presented in Appendixes A and B of the IGMP/CSPCP Sampling Plan.

Electromagnetics. An electromagnetic induction survey will be conducted east of the present landfill to identify and delineate the three burial trenches in this area. The survey will be conducted using a Geonics EM-31 terrain-conductivity instrument in a continuous recorder mode. Conductivity measurements will be taken on 30-ft centers across the burial trenches. Closely spaced measurements will be taken at the edges of anomalous areas for boundary definition.

Conductivity measurements in millimhos per meter (mmhos/m) will be plotted and contoured to identify areas of anomalous conductivities. These anomalous areas should be indicative of source areas.

Magnetometer. A magnetometer survey will be conducted over the burial trenches to screen for buried metallic objects. This survey will be conducted with a portable proton memory magnetometer and will supplement the electromagnetic induction survey. This survey will be conducted on 15-ft centers within the surveyed grid.

Metal Detection. Areas believed to contain metallic objects (from electromagnetic induction and magnetometer data) will be investigated further using a White's metal detector. Buried metallic objects located with the metal detector will be flagged to avoid drum puncture during soil sampling efforts.

Electrical Resistivity Soundings. Two vertical electrical resistivity soundings will be conducted at each of the three burial trenches at the Present Landfill Site to determine the approximate depth of each trench. A Bison Instrument Model 2365 resistivity instrument will be used for this source characterization effort. These soundings will provide a vertical profile of resistivity, which should indicate the depth of waste disposal water table and bedrock. The soundings will be made to an effective depth of about 50 ft.

3.5.2.4. Soil Gas Surveys

Soil gas surveys at the Present Landfill Site will be primarily used to assist in landfill closure design. Methane and hydrogen sulfide soil gas sampling will be performed on the existing landfill cap to evaluate gases presently trapped in the landfill. Approximately 20 soil gas sampling points in the landfill cover are anticipated.

Additional soil gas sampling will be conducted over the burial trenches and spray irrigation areas to characterize these sources. These surveys will be performed on 90-ft surveyed grids following procedures in Appendix A of the IGMP/CSPCP Sampling Plan.

3.5.2.5. Soil/Waste Sampling

Soil and waste sampling will be performed at the Present Landfill Site to characterize the cover materials on the present landfill, the contents of the burial trenches east of the landfill, and the soils in the spray irrigation areas. Specific sampling locations will be defined based on geophysical and soil gas survey results; however, at least two borings will be drilled into each trench and each spray irrigation area, as appropriate. Approximately 20 borings through the landfill cover are anticipated at this time (Plate 3). Physical testing will be performed on samples from these borings to evaluate the integrity of the existing landfill cover.

Borings through the trenches and spray irrigation areas will extend though each unit down to bedrock. Samples will be analyzed for the parameters listed in Table 3.1.

3.5.3. Migration Pathway and Plume Characterization

3.5.3.1. Soil Gas Surveys

Soil gas surveys will not be conducted at the Present Landfill Site for plume delineation. Source characterization soil gas surveys are discussed in Section 3.5.2.4.

3.5.3.2. Soil Sampling

Soil sampling may be performed to delineate the extent of soil contamination and to characterize migration pathways at the Present Landfill Site. Specific sampling locations will be based on the soil gas survey results. Samples will be collected from boreholes and monitoring well installations as described in Appendix A of the IGMP/CSPCP Sampling Plan and analyzed for the parameters listed in Table 3.1.

3.5.3.3. Monitor Well Installation and Groundwater Sampling

Three new monitor wells are currently anticipated at the Present Landfill Site (Plate 4). A well pair will be installed in the tributary at the base of the landfill pond dam to characterize downgradient groundwater quality and saturation conditions. An alluvial well will be installed in the tributary east of the new downgradient well pair to define the extent of saturation in valley fill alluvium.

There are several existing monitor wells in the vicinity of the present landfill that will be used in characterizing the groundwater pathway at the site. Well pair 10-86 (alluvial well) and 9-86 (bedrock well) are located west of the present landfill and serve to characterize upgradient conditions. Well pair 7-86 (alluvial well) and 8-86 (bedrock well) are located east of the present landfill at the toe of the fill. This pair is located to allow characterization of groundwater conditions immediately downgradient of the landfill. Alluvial wells 6-86 and 5-86 are located further east of the present landfill in the tributary to evaluate the extent of saturation and contaminant plumes.

Groundwater samples will be collected from new and existing wells at the Present Landfill Site following the procedures in Appendix A of the IGMP/CSPCP Sampling Plan. Samples will be analyzed for the parameters listed in Table 3.2. Based on results of soil/waste sampling performed during source characterization, this parameter list may be modified to include additional contaminants.

3.5.3.4. Surface Water and Sediment Sampling

Surface water samples will be collected from established sampling locations upstream and downstream from the Present Landfill Site. Included will be stations along Church Ditch, McKay Ditch, and the unnamed tributary of Walnut Creek. Stratified sampling of the landfill pond will also be performed to characterize its contents. Surface water samples will be collected from any springs or seeps occurring on the hillsides north or south of the landfill pond. Additional surface water and/or sediment samples may be collected based on soil gas survey results. Samples will be analyzed for the parameters in Tables 3.1 and 3.2 as appropriate.

3.6. SOLAR EVAPORATION PONDS SITE

3.6.1. Site Description

3.6.1.1. Solid Waste Management Unit Descriptions

The Solar Evaporation Ponds Site consists of three separate ponds (SWMU Ref. No. 101): 207C (western pond), 207A (central pond), and 207B (eastern pond). Pond 207B is separated into three sectors (north, central and south). Ponds 207A and 207C contain low-level radioactive liquid process wastes (high in nitrates) being held for evaporation, treatment and solidification. Pond 207B North receives groundwater pumped from the interceptor trench north of the solar ponds. Pond 207B Center contains treated sanitary wastewater from the treatment plant. Pond 207B south is currently empty.

The solar evaporation ponds were constructed in separate phases between 1953 and 1970. Originally, the solar evaporation ponds were a single, two-celled, clay-lined impoundment near Building 779. This pond held low-level radioactive process wastes (high in nitrates) and effluent (mostly water) from treatment of acidic liquid wastes in Building 774. The original pond was used regularly from 1953 through 1965 and was removed as part of the construction of pond 207C. The effluent from the acidic waste treatment process was thick with aluminum hydroxide and difficult to filter. Therefore, an additional pond, 207A, was constructed in 1956 to hold the effluent prior to solidification and shipment offsite. Leakage problems developed in the planking and asphalt-lined ponds, so the three 207B ponds were constructed in 1960. The 207B ponds were also lined with planking and asphalt and eventually began to leak. The liners were repeatedly patched with various materials. In 1970, all of the ponds (207A and 207B) were full, so pond 207C was constructed for additional storage and evaporative potential. Pond 207C was constructed on the site of the original clay lined pond.

In addition to the high nitrate, low-level radioactive process waste and the treated aluminum hydroxide waste, the solar evaporation ponds have received sanitary sewage sludge, lithium metal, sodium nitrate, ferric chloride, lithium chloride, sulfuric acid, ammonium persulfate, hydrochloric acid, nitric acid, hexavalent chromium and cyanide solutions. To the greatest extent possible, oils and solvents were not sent to the ponds so that surface scum would not hamper evaporation.

A series of trenches and drains was constructed on the north facing slope below the ponds to collect leakage between 1971 and 1981. Because of various construction projects in the area, only the most recent french drain, constructed in 1981, is functional. This system more than covers the east-west dimensions of the ponds and appears to be effective in collecting the seepage.

3.6.1.2. Surface Water

Surface water flows to both North and South Walnut Creeks from the solar evaporation ponds area. The northern slope of the solar evaporation ponds and the units in the 700 area drain toward the north (North Walnut Creek). Most of the runoff is contained by the perimeter road and enters the groundwater interceptor system which extends to the surface. The triangle area (SWMU ref. no. 165) drains directly to North Walnut Creek through a culvert. Runoff from the triangle area is collected in the A-series retention pond system. The southern areas of the solar evaporation ponds drain toward South Walnut Creek and runoff is collected in the B-series retention ponds.

3.6.1.3. Groundwater

Groundwater occurs in both the Rocky Flats Alluvium and in bedrock materials in the vicinity of the solar evaporation ponds. The Rocky Flats Alluvium varies in thickness from about 5 to 12 ft beneath the terrace, and the ponds themselves are probably underlain by a thin veneer of Rocky Flats Alluvium. The top of bedrock forms a mild structural ridge that trends down to the east-northeast. The northern slope from the ponds toward North Walnut Creek has been extensively reworked and most of the unconsolidated materials have been removed (claystone bedrock is exposed over much of the slope). The alluvium extends to the east along the ridge, although it is fully penetrated by the perimeter road.

Bedrock immediately beneath the Rocky Flats Alluvium in the vicinity of the solar evaporation ponds consists of claystone and sandstone of the Arapahoe Formation. Twelve borings have been made in the immediate vicinity of the ponds, and sandstone comprises roughly 20 percent or less of the bedrock materials within 150 ft of the surface. The beds dip approximately 15 degrees to the east.

Alluvial groundwater flow in the vicinity of the ponds is generally to the north. There appears to be an area of unsaturated alluvium south of the ponds (Hurr 1976 and DOE 1986f) that indicates no flow in the alluvium to the south. The alluvium is fully penetrated by the perimeter road east of the ponds. There is no spring at the outcrop; therefore, there is no alluvial groundwater flow to the east. In addition, claystone bedrock is exposed on the slope to the north of the ponds. It appears that the alluvium beneath the ponds is recharged by subsurface flow from the west, and that the discharge is to the north in the form of subsurface flow in surficial materials and overland flow over the exposed claystone bedrock. Most, if not all of this water appears to be collected in the interceptor trench system.

Flow in bedrock is less well defined. Regional studies (Hurr 1976 and Robson 1981) indicate relatively shallow gradients of about 0.03 to the east (downdip). Site-specific data are currently lacking. However, it seems likely that there is a gradient to the east plus a gradient along the strike in the near-surface, controlled by topography. In addition, there is a downward gradient between the surficial materials and bedrock of about 0.3 in areas of continuous saturation between the two materials. It appears that there is not continuous saturation between the two materials at the eastern and southern edges of the ponds. These areas of discontinuous saturation between the materials are on the edges of alluvium saturation, where water is not always available to recharge the bedrock system.

Groundwater quality in surficial materials in the vicinity of the solar evaporation ponds is characterized by high TDS concentrations, high nitrate concentrations, high strontium concentrations, and possibly elevated radionuclides. Volatile organic compounds have been detected intermittently near the solar evaporation ponds.

3.6.2. Source Characterization

3.6.2.1. Geophysical Surveys

Geophysical surveys will not be performed at the Solar Evaporation Ponds Site; the pond locations are well defined.

3.6.2.2. Soil Gas Surveys

Soil gas surveys will not be conducted at the Solar Evaporation Ponds Site; the pond locations are well defined.

3.6.2.3. Soil/Waste Sampling

The liquids in the ponds and the sludges in Pond 207A have been adequately characterized by previous investigations (DOE 1986f). The sediments in the 207B ponds and in Pond 207C will be sampled during CEARP Phase 2 investigations. Soil sampling around the solar evaporation ponds will be conducted to evaluate the extent of soil contamination and is discussed in Section 3.6.3.2.

3.6.3. Migration Pathway and Plume Characterization

3.6.3.1. Soil Gas Surveys

Soil gas surveys will not be performed at the Solar Evaporation Ponds Site. Detailed soil and groundwater sampling at the site adequately defines groundwater plumes.

3.6.3.2. Soil Sampling

Soils on the berms of the solar evaporation ponds and on the hillside north of the ponds will be sampled to evaluate the extent of soil contamination. Approximately 20 borings are anticipated (Plate 3). Three borings will be located on the eastern berm of pond 207B, two borings will be drilled into the berm between ponds 207A and 207B, and two borings will be located on the berm between ponds 207A and 207C. Another six boreholes will be drilled on the hillside north of the solar evaporation ponds. Borings will extend to the water table or to the top of bedrock if top of bedrock is above the water table.

Soil sampling will be implemented in phases. After analyzing results from soil sampling on the pond berms and the north hillside, another 7 to 10 soil borings may be drilled downgradient of the ponds outside the perimeter security zone. These borings may extend down the hillside to North Walnut Creek to delineate areas of contaminated soil. Soil sampling and analysis details will be provided in the revised Solar Evaporation Ponds Closure Plan.

3.6.3.3. Monitor Well Installation and Groundwater Sampling

Twenty-two new monitor wells were drilled around the solar evaporation ponds as part of the initial CEARP Phase 2b site characterization (remedial investigation). This monitoring system rings the solar evaporation ponds with alluvial and bedrock wells. In addition, there are several alluvial and bedrock monitor wells downgradient of the ponds in both North and South Walnut Creeks.

Because of the extensive groundwater monitoring system already in place at the solar evaporation ponds, only two new monitor wells are proposed downgradient of the ponds (Plate 4). One well will be installed in North Walnut Creek immediately north of existing well 13-86 to characterize groundwater flow in the North Walnut Creek valley fill alluvium. Another well will be located on the hillside north of the ponds.

3.6.3.4. Surface Water and Sediment Sampling

Surface water samples will be collected from established sampling locations up and downstream from the Solar Evaporation Ponds Site. Included will be stations along North Walnut Creek and South Walnut Creek. Surface water samples will also be collected from any springs or seeps occurring on the hillsides north of the solar evaporation ponds. Samples will be analyzed for the parameters in Tables 3.1 and 3.2 as appropriate.

Table 3.1. Source Sampling Parameters

Metals[a,b]	
Hazardous Substance List - Metals	
Beryllium	
Chromium (hexavalent)	
Lithium	
Strontium	
Organics	
Hazardous Substances List - Volatiles[b]	
Oil and Grease[a]	
Radionuclides[b]	
Gross Alpha	
Gross Beta	
Uranium 233, 234, and 238	
Americium 241	
Plutonium 239	
Strontium 90	
Cesium 137	
Tritium	
Other	
TCLP	
EP Toxicity	
Characteristics (e.g., ignitability, corrosivity, reactivity)	
pH	
Cation Exchange Capacity	

[a]These analyses will be performed on only one-third of the samples.
[b]These analyses may be performed on sediments.

Table 3.2. Groundwater and Surface Water Sampling Parameters

Field Parameters
pH
Specific Conductance
Temperature
Dissolved Oxygen*

Indicators
Total Dissolved Solids
Total Suspended Solids*

Metals**
Hazardous Substances List - Metals***
Beryllium***
Calcium
Chromium (hexavalent)***
Iron
Lithium***
Magnesium
Manganese
Potassium
Sodium
Strontium***
Zinc

Anions
Carbonate
Bicarbonate
Chloride
Sulfate
Nitrate

Organics
Hazardous Substances List - Volatiles
Oil and Grease***

Radionuclides
Gross Alpha
Gross Beta
Uranium 233, 234, and 238
Americium 241
Plutonium 239
Strontium 90
Cesium 137
Tritium

Table 3.2. (Continued)

Other
EP Toxicity
Characteristics (e.g., ignitability, corrosivity, reactivity)

---

* for surface water samples only
** dissolved metals for groundwater samples,
total and dissolved metals for surface water samples
***These analyses will be performed on only one-third of the samples.

4. SAMPLE CONTAINERS, PRESERVATION, AND HOLDING TIMES

Protocols for sample containers, sample preservation, and holding times will conform to those specified in the CGMP and IGMP/CSPCP Sampling Plans and Quality Assurance/Quality Control Plans.

5. SAMPLE CONTROL AND DOCUMENTATION

Procedures for sample control and documentation will conform to those specified in the CGMP and IGMP/CSPCP Quality Assurance/Quality Control Plans.

6. SAMPLE HANDLING, TRANSPORT, AND STORAGE

Procedures for sample handling, transport, and storage will conform to those specified in the CGMP and IGMP/CSPCP Quality Assurance/Quality Control Plans.

7. SAMPLE PREPARATION AND ANALYSES

Procedures for sample preparation and analyses will conform to those specified in the CGMP and IGMP/CSPCP Quality Assurance/Quality Control Plans.

8. REFERENCES

DOE 1986b: "Comprehensive Environmental Assessment and Response Program Phase 1: Draft Installation Assessment Rocky Flats Plant," US Department of Energy unnumbered draft report, April 1986.

DOE 1986f: "Resource Conservation and Recovery Act Part B - Operating Permit Application for USDOE Rocky Flats Plant, Hazardous and Radioactive Mixed Wastes," US Department of Energy unnumbered report, November 1986.

DOE 1986g: "Resource Conservation and Recovery Act Part B - Post-Closure Care Permit Application for USDOE Rocky Flats Plant, Hazardous and Radioactive Mixed Wastes," US Department of Energy unnumbered report, November 1986.

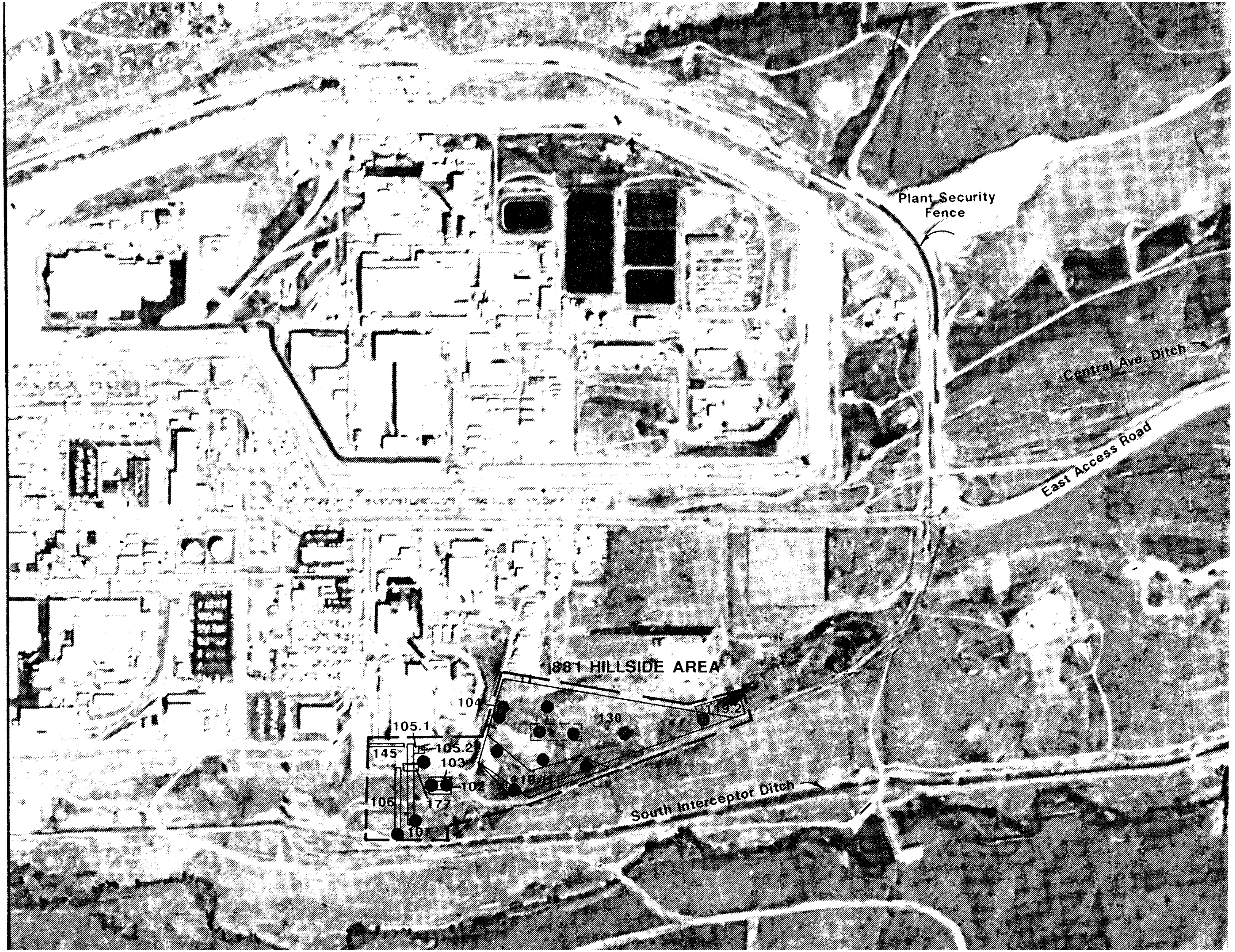
DOE 1986h: "Draft Preliminary Prioritization of Sites," US Department of Energy unnumbered draft report, July 1986.

Hurr 1976: R.T. Hurr, "Hydrology of a Nuclear-Processing Plant Site, Rocky Flats, Jefferson County, Colorado," US Geological Survey Open-File report 76-268, 1976.

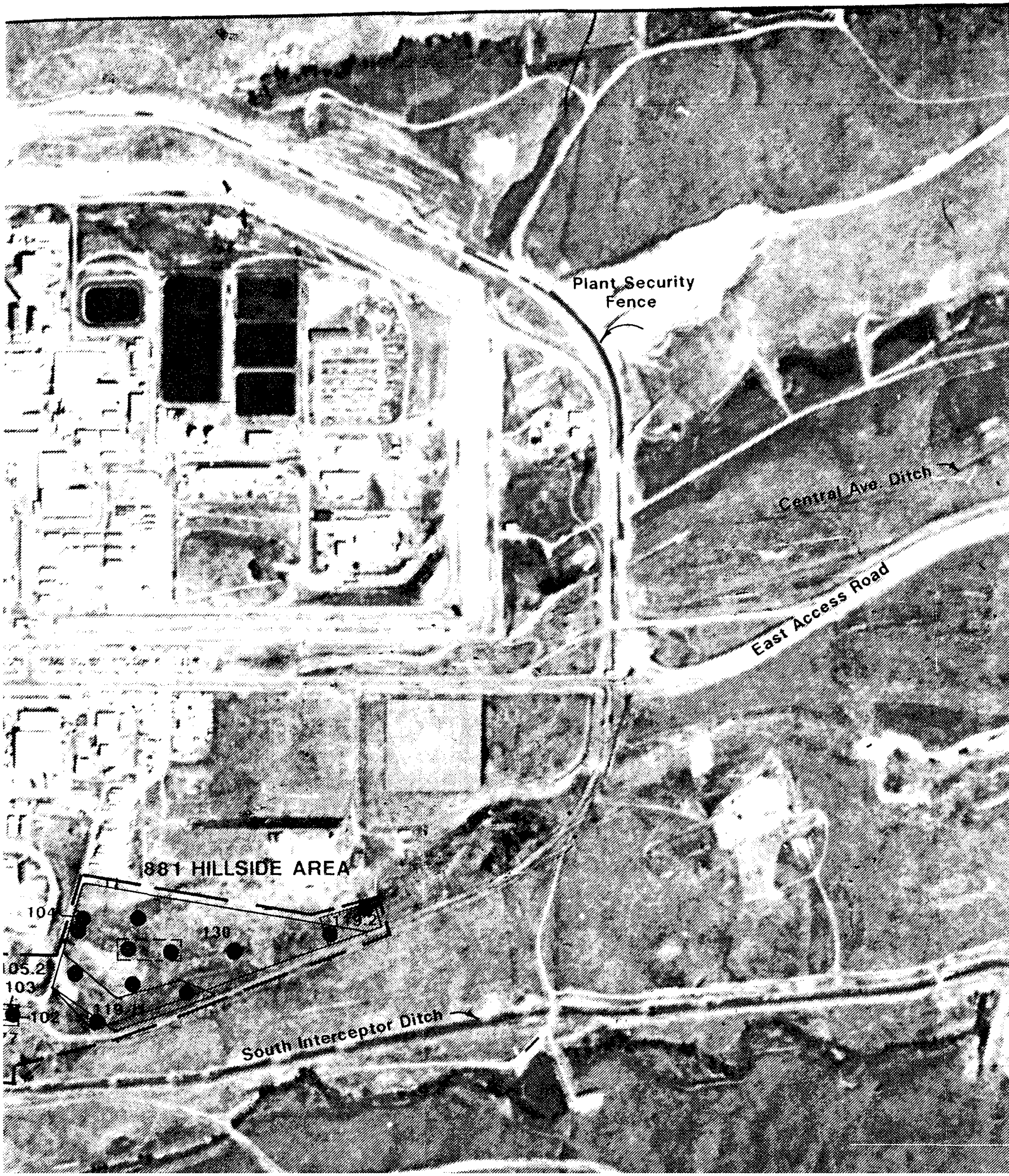
RI 1986a: "Annual Environmental Monitoring Report: January-December 1985," Rockwell International Rocky Flats Plant, Golden, Colorado report RFP-ENV-85, April 1986.

RI 1986b: "Rocky Flats Plant Radioecology and Airborne Pathway Summary Report," Rockwell International, Rocky Flats Plant, Golden, Colorado unnumbered report, December 1986.

Robson 1981: Robson, S.G., J.C. Romero and S. Jawistowski, "Geologic Structure, Hydrology, and Water Quality of the Arapahoe Aquifer in the Denver Basin, Colorado," US Geologic Survey Hydrologic Atlas HA-647, 1981.



881 HILLSIDE AREA
104
130
105.1
105.2
145
103
102
106
177
107
Plant Security Fence
Central Ave. Ditch
East Access Road
South Interceptor Ditch



EXPLANATION

● Proposed Soil Boring Locations

☐ Location of Solid Waste Management Unit

⬚ Location of Areas of Interest Within Solid Waste Management Unit

101 Solid Waste Management Unit Reference Number (Rockwell International, 1986a)

NOTES:

1) Base map photo-enlarged from aerial photography of Rocky Flats Plant taken May 20, 1986.

2) The locations of the solid waste management units have been located as accurately as possible, based on information available prior to 1987 remedial investigation.

1" = 500'

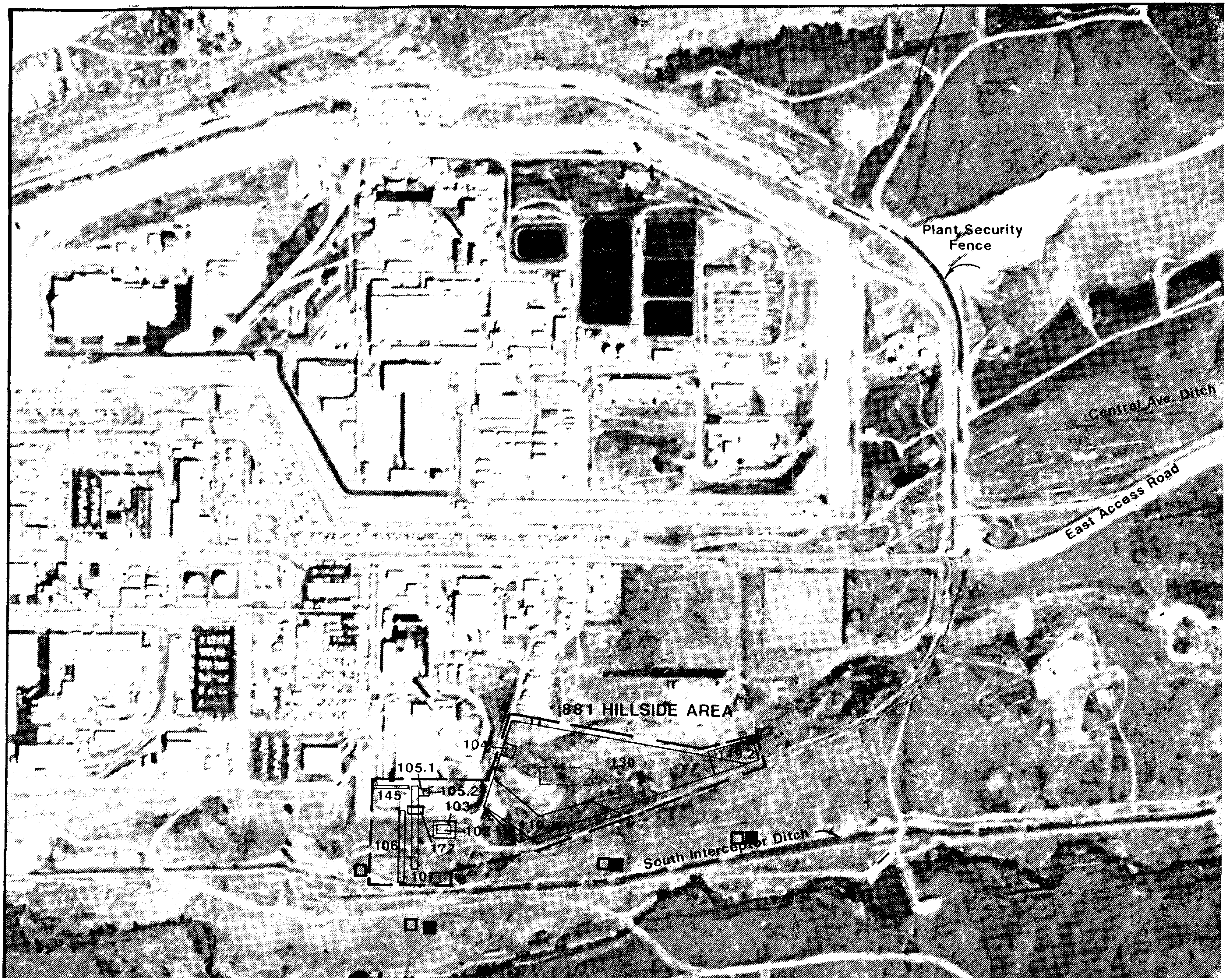
0 500' 1000'

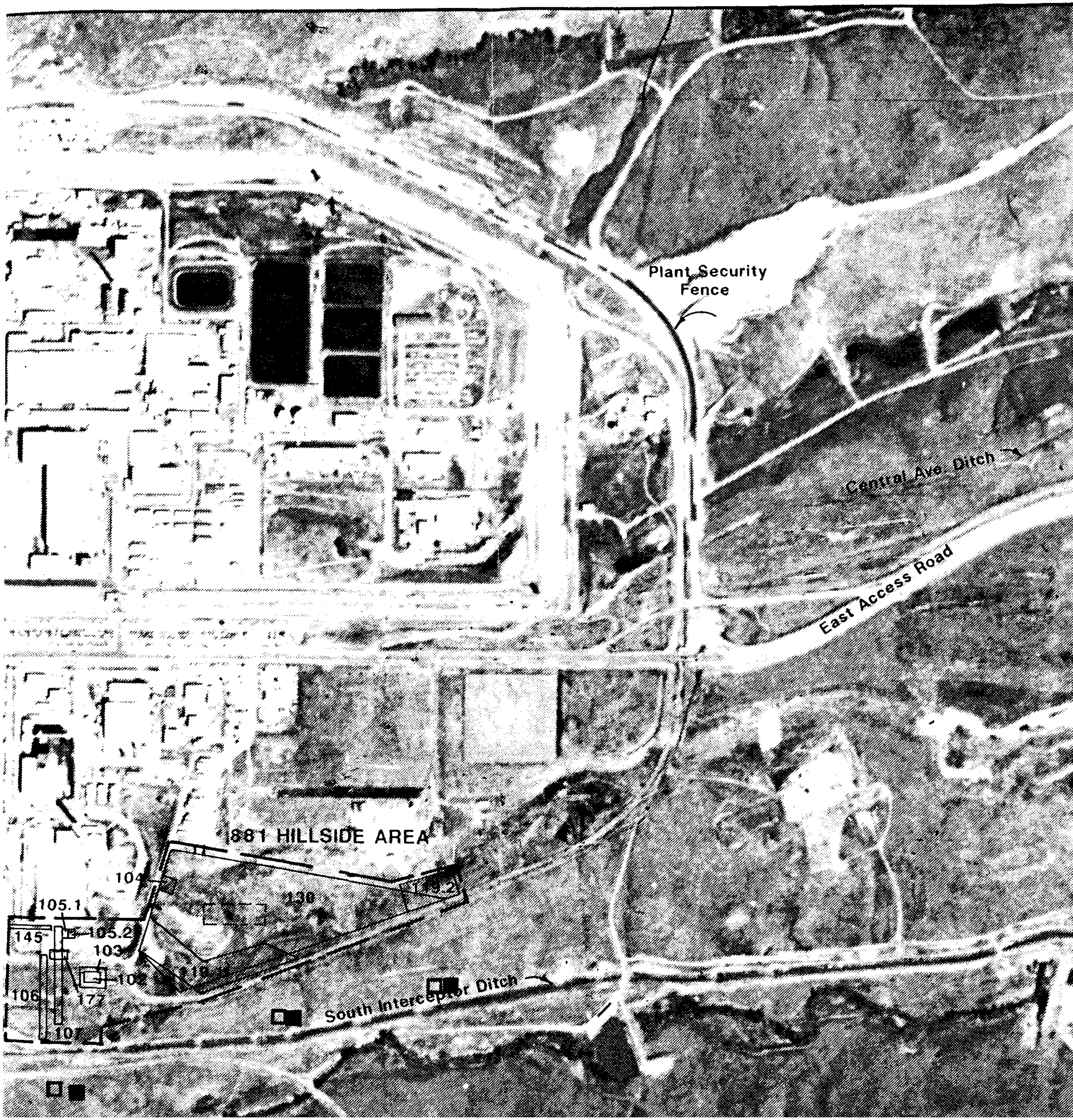
PLATE III:

881 Hillside Area

Remedial Investigation

Proposed Soil Boring Locations


Plant Security
Fence
Central Ave. Ditch
East Access Road
881 HILLSIDE AREA
104
130
119.2
105.1
145
105.2
103
102
119.1
106
177
107
South Interceptor Ditch



EXPLANATION

- Proposed Alluvial Well
- Proposed Bedrock Well
- Initial CEARP Phase 2 Alluvial Well
- Initial CEARP Phase 2 Bedrock Well
- Existing Wells from Previous Investigations
- Location of Solid Waste Management Unit
- Location of Areas of Interest Within Solid Waste Management Unit
- 101 Solid Waste Management Unit Reference Number (Rockwell International, 1986a)

NOTES:

1) Base map photo-enlarged from aerial photography of Rocky Flats Plant taken May 20, 1986.

2) The locations of the solid waste management units have been located as accurately as possible, based on information available prior to 1987 remedial investigation.

1" = 500'

0 500' 1000'

PLATE IV:

881 Hillside Area

Remedial Investigation

Existing and Proposed

Appendix B

APPENDIX B

REPORT OF GEOPHYSICAL INVESTIGATIONS
881 HILLSIDE AREA
ROCKY FLATS PLANT
GOLDEN, COLORADO

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SECTION 1

INTRODUCTION

Geophysical surveys of the 881 Hillside area of the Rocky Flats Plant, Jefferson County, Colorado, have been completed as specified in the CEARP IGMP/SSMP Sampling Plan, dated February 1987, for the facility. The surveys were completed as part of the CEARP investigations of high priority sites at the Rocky Flats Plant. Geophysical surveys were based on data available prior to 1987 remedial investigations.

The purpose of the geophysical surveys was to attempt to identify the location of suspected SWMUs or other potential sources, and/or plumes of environmental contaminants, by locating areas of high or low responses (anomalies) on various geophysical instruments. Once anomalies have been identified, borings and monitoring wells will be located to verify the significance of these anomalous areas as part of the overall site investigation program. In addition, electrical resistivity was used to provide information about site stratigraphy. Stratigraphic information was obtained by performing vertical electrical soundings (VES) at various locations across the site.

This report presents geophysical survey results. Results of the borehole and monitoring well programs, and their confirmation or explanation of the geophysical anomalies, will be presented in the remedial investigation report.

SECTION 2

SITE BACKGROUND

Information available at the time that the geophysical surveys were done indicate that surficial materials at the 881 Hillside area consist of Rocky Flats Alluvium, colluvium, and valley fill alluvium. The Rocky Flats Alluvium beneath the land surface (at and north of Building 881) varies in thickness from 4 to 14 feet. The Rocky Flats Alluvium is a poorly sorted deposit of sand, gravel, and cobbles that contains some clay horizons. The 881 Hillside itself is mantled with slopewash material (colluvium) consisting of 2 to 5 feet of sandy clay underlain by 4 to 5 feet of sandy gravel. The materials underlying the slope merge downhill with the valley fill alluvium. The valley fill alluvium consists of thin (3 to 8 feet thick) sandy gravels. Bedrock beneath the 881 Hillside area at monitoring well 59-86 consists of approximately 10 feet of claystone underlain by 7 to 12 feet of sandstone. The sandstone is in turn underlain by additional claystone. These claystones and sandstones dip approximately 15 to 30^{o} to the east (DOE, 1986f), as discussed in the main body of the report.

The hydrogeology of the 881 Hillside area appears to be dominated by flow from the Rocky Flats Alluvium, through the colluvium, and into the valley fill alluvium. The flow system is complicated by apparently unsaturated portions of the Rocky Flats Alluvium both west and east of Building 881. Groundwater occurs in the sandy gravel of the slopewash material and in the sandstone bedrock. The static water level in the sandstone appears to be about 25 feet lower than in the slopewash, based on water measured levels in 59-86 and 69-86 on June 24, 1987 .

Results of groundwater sampling (DOE, 1986f) indicate that groundwater in both bedrock and surficial materials is of poorer quality than the upgradient groundwater in the Rocky Flats Alluvium. The groundwater at the 881 Hillside area apparently contains more sodium (as a percentage of major ions) than upgradient alluvial waters and has total dissolved solids (TDS) concentrations in the range of 1000 milligrams per liter (mg/l). Radioactive constituent values are approximately equal to upgradient values, and dissolved metal concentrations are generally similar. However, strontium metal concentrations are higher at the 881 Hillside area than at upgradient locations. Volatile organic compounds (VOCs) were detected in only one area of the 881 Hillside area. Significant concentrations (greater than 1000 parts per billion) of 1,1-dichloroethylene (1,1, DCE), 1,1,1-trichloroethane (1,1,1 TCA), trichloroethylene (TCE), and tetrachloroethylene (PCE) were detected in well 9-74 during 1986.

The 881 Hillside location has been the site of various spills and disposal operations during the history of the plant. Presented below are descriptions of the ten solid waste management units (SWMUs) comprising the 881 Hillside Area taken from Rockwell International (1986a). Figure 1 shows the site locations.

- Oil Sludge Pit (SWMU Ref. No. 102) - In 1958, approximately 30 to 50 drums of oil sludge from cleaning storage tanks were emptied into a pit south of Building 991 and covered with soil.

- Chemical Burial (SWMU Ref. No. 103) - An area south of Building 881 was reportedly used to bury unknown chemicals.

- Liquid Dumping (SWMU Ref. No. 104) - Prior to 1969, the area east of Building 881 was reportedly used for dumping liquid and disposing of empty drums. The types of liquids and residual materials in the drums is unknown.

- Out-of-Service Fuel Tanks (SWMU Ref. No. 105) - Asbestos was reportedly placed in two out-of-service No. 6 fuel oil tanks located south of Building 881. The tanks were then filled with concrete.

- Outfall (SWMU Ref. No. 106) - An outfall south of Building 881 may discharge on an occasional basis. The outfall is apparently a cleanout pipe for an overflow line from a cooling tower.

- Hillside Oil Leak (SWMU Ref. No. 107) - In 1973, No. 6 fuel oil from an undetermined source was observed on the hillside south of Building 881. Straw was used to limit the spread of the oil. The oil-soaked straw and soil were removed and placed in the present landfill.

- Multiple Solvent Spills (SWMU Ref. No. 119) - In 1967, two areas east of Building 881 and along the southern perimeter road were used as solvent storage facilities. Minor leaks and spills may have occurred in these areas. The facilities were removed by April 1972.

- Radioactive Site - 800 Area Site #1 (SWMU Ref. No. 130) - An area east of Building 881 was used for the disposal of 320 tons of plutonium-contaminated soil (about 7 dpm/g alpha activity) from the Building 776 fire. The area was also used for the disposal of approximately 60 cubic yards of plutonium-contaminated soil (about 250 dpm/g alpha activity) from Building 774 waste storage tank area. Site #1 was covered with about 1 to 2 feet of soil.

- Sanitary Waste Line Leak (SWMU Ref. No. 145) - In January 1981, the sanitary waste line located south of Building 881 leaked. An earthen dike was constructed to prevent runoff into the south interceptor ditch and the line was repaired. The sanitary waste line carried radioactive laundry effluent from about 1969 to 1973. Whether other hazardous materials have ever been carried in the line is unknown.

- Building 885 Drum Storage Area (SWMU Ref. No. 177) - The Building 885 Drum Storage Area will be closed under Interim Status (40 CFR 265). Complete information on this solid waste management unit is provided in the Interim Status closure plan.

SECTION 3

METHODS

3.1 GRID SURVEY

A grid system was established on the 881 Hillside area in order to provide lateral control of measurement location. Survey stations were staked at 60-foot intervals and marked with a coordinate designation based on the Rocky Flats Plant grid system. All geophysical survey points were located based on this coordinate system.

3.2 ELECTROMAGNETIC CONDUCTIVITY

Electromagnetic conductivity (EM) surveys of the 881 Hillside area of Rocky Flats Plant were conducted using both EM-34-3 and EM-31 Terrain Conductivity Meters manufactured by Geonics, Ltd. Electromagnetic techniques of measuring terrain conductivity operate by imparting an alternating current to a transmitter coil. Current passing through the transmitter coil produces a magnetic field which in turn induces small currents in the underlying strata. Currents within the geologic materials produce a secondary magnetic field which is sensed by the receiver coil. It has been shown that under certain constraints, the ratio of the secondary to the primary magnetic field is proportional to terrain conductivity (Geonics, 1980). This fact allows conductivity to be read directly from the instrument in units of millimhos per meter (mmhos/m).

The EM-34-3 unit measures the average conductivity of materials between two hand-held coils spaced 10, 20 or 40 meters apart. The effective depth of penetration is variable by altering intercoil spacing and coil orientation. EM-34-3 conductivity was measured at 253 survey stations, in both horizontal and vertical dipole configurations, with a coil separation of 10 meters. Measurements taken in the horizontal dipole mode yielded an effective depth of exploration of 7.5 meters with the largest signal contribution from near-surface materials. Vertical dipole measurements yielded an effective depth of exploration of 15 meters with a smaller signal contribution from near-surface materials. The survey was run on a 60-foot grid system across the site. This spacing was chosen to allow nearly continuous conductivity data to be obtained along the survey lines.

The EM-31 unit measures the average conductivity of materials between two fixed coils spaced 3.7 meters apart. This configuration yields an effective depth of exploration of 6 meters. The survey was conducted at 15-foot intervals along east-west oriented survey lines. Survey lines were spaced at 30-foot intervals, except where examination of the data showed that additional data collection would aid in the definition of anomalous areas. A total of 2,172 data points were collected with the EM-31.

Both EM-34-3 and EM-31 were utilized to characterize the site because of the characteristic differences between the two instruments. The EM-34-3 is best suited to screen broad areas of a site for changes in conductivity. The EM-34-3 is less sensitive to small conductors, such as single drums or small pits, than is the EM-31 because of its relatively large coil spacing. However, the EM-34-3 is capable of surveying to a greater depth and is less sensitive to surficial materials (soils) in the vertical dipole configuration than is the EM-31. This gives the EM-34-3 the capability of identifying contaminant plumes, more readily than the EM-31, in areas where there is sufficient conductivity contrast.

3.3 RESISTIVITY

Nine vertical electrical soundings (VES) surveys were completed at the 881 Hillside area. VES-1 was completed north of the north ridge as a background survey point. VES-2 and VES-3 were completed on electromagnetic conductivity anomalies at the east end of the site and near the east end of SWMU 119.2, respectively. VES-4 and VES-6 were completed at electromagnetic conductivity and magnetic anomalies near monitoring wells 59-86, 60-86, and 69-86. VES-7 was located immediately south of the security fence, south of Building 881, as a background survey for the southwestern corner of the 881 Hillside area. VES-5 and VES-8 were also completed at electromagnetic conductivity and magnetic anomalies at the southwestern corner of the area. VES-9 was completed at the reported location of SWMU 104. The locations of the VES points are presented below and shown on Figure 2.

LOCATION OF VES POINTS

Sounding No.	Rocky Flats Plant Grid System Coordinates	
1	N-35420	E-21520
2	N-35420	E-22030
3	N-35060	E-21760
4	N-34790	E-21190
5	N-34760	E-20710
6	N-34820	E-21100
7	N-35000	E-20740
8	N-34735	E-20650
9	N-35330	E-21160

All of the VES surveys were made using a Bison Model 2390 transmitter and receiver. This system is a microprocessor controlled signal enhancement unit with automatic self potential removal and current control. The unit displays the reading in the form of millivolts. The Bison offset sounding cable system (BOSS Model 2365) and steel stake electrodes were used for all VES surveys.

Electrical resistivity measures the electrical resistivity of the soil by passing an electrical current into the ground from a pair of electrodes and measuring the electrical voltage with a second pair of electrodes. Resistivity data is generally recorded as apparent resistivity, ρ_a, which can be found from the equation: $\rho_a = K \times V/I$; where V is the observed voltage, I is the injected current, and K is the geometric shape factor. The basic unit of resistivity measurement and apparent resistivity is the ohm-meter. K is a shape function of the geometry of the electrode arrangement typically called an array.

The Wenner array is the most commonly used array for hydrogeologic studies. The Wenner array was selected for its ease of field operation and data analysis, and its sensitivity to soil resistivity changes caused by variation in moisture content. Its main advantages are that it has a much lower sensitivity to geologic noise and localized changes in soil resistivity unrelated to large-scale features of interest, and it returns a relatively high voltage for a small transmitter current allowing the use of smaller transmitters. Its major disadvantage lies in having a somewhat lower vertical resolution and much lower horizontal resolution than other arrays. For the Wenner array, the geometric shape factor is given by $K=2\pi a$, where a is the spacing between electrodes.

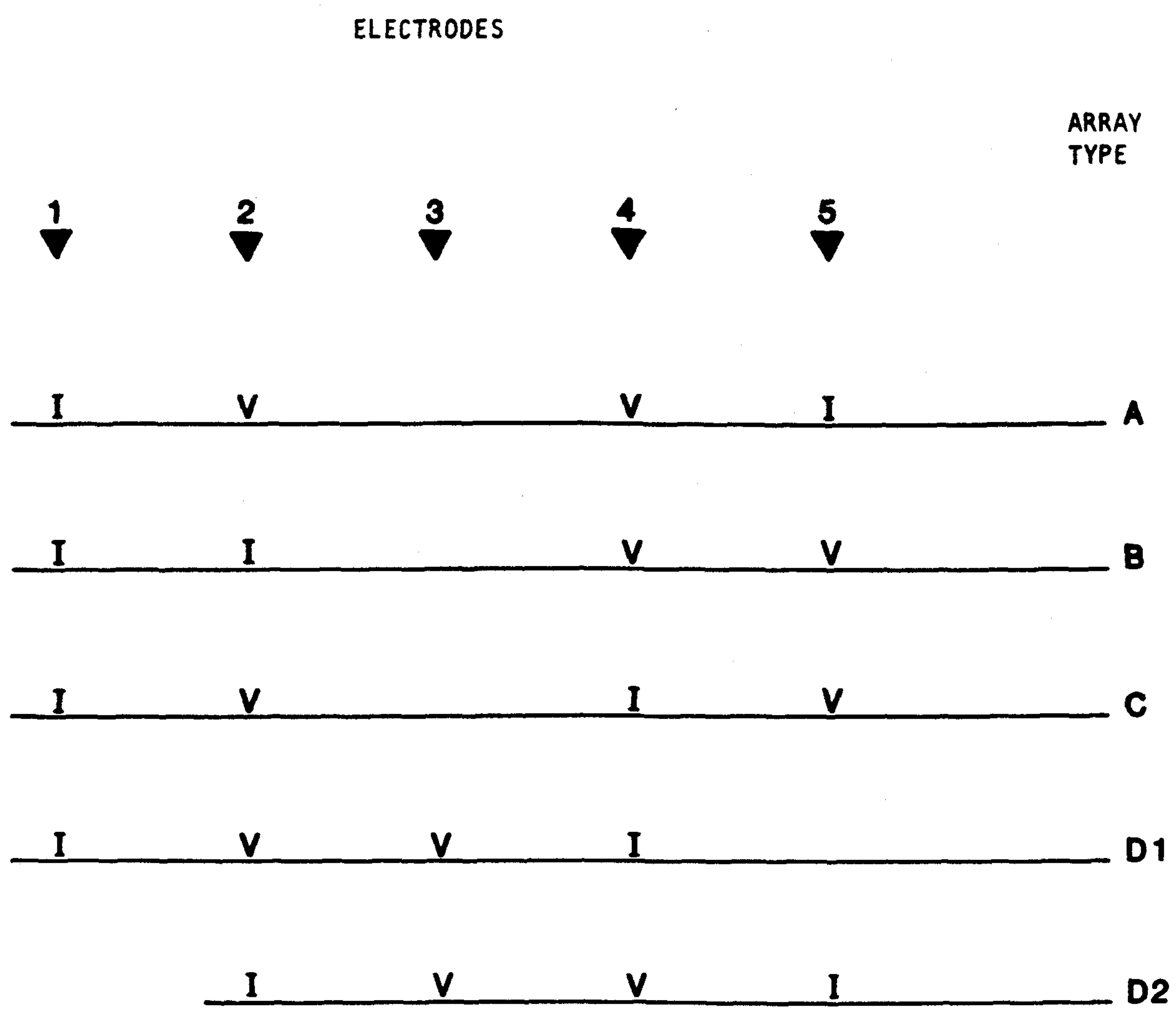
The apparent resistivity reading is not indicative of the resistivity at any single depth but is an average of soil resistivity over a range of depths. The depth of exploration is proportional to the a-spacing used with the principal response coming from a depth of about 1/3 to 1/2 of the a-spacing. VES surveys are conducted by making a series of measurements starting with a small a-spacing, usually less than 1 meter, and increasing the spacings logarithmically out to several tens or even hundreds of meters.

The BOSS system utilizes an array of cables designed to allow completion of Wenner soundings very quickly. The manufacturer, Bison Instruments, Inc., indicates that significant reductions in the effects of geologic noise should result. The cables have electrode takeouts in a geometric series with the a-spacing increasing by a factor of two. Five different array measurements are made at each a-spacing as shown on Figure 3. Measurements D-1 and D-2 consist of a pair of overlapping or "offset" Wenner arrays. If the local stratigraphy consists of a series of flat layers, both arrays D-1 and D-2 will give the same approximate apparent resistivities. Millivolt values from the five array measurements at each a-spacing are used to calculate a single Wenner resistivity reading.

3.4 MAGNETOMETRY

Thirty-four magnetic survey lines were completed at the 881 Hillside area. The earth's total magnetic field intensity was measured at 1,585 survey stations. The survey was conducted using an EG&G Geometrics Memory Proton Precession Magnetometer, Model G-856X, with a gradiometer option.

The magnetic method used to measure the earth's total magnetic field intensity temporarily polarizes spinning hydrocarbon protons in the magnetometer sensor. The temporary polarization is obtained through the amplification of a uniform magnetic field generated by a current passing through a coil of wire. When the current is removed, the spin of the protons causes them to revolve in the direction of the earth's



LEGEND

I Electrodes used as a transmitter.

V Electrodes used as a receiver.

6 007 87	Chen & Associates	ARRAY TYPES USED IN BOSS SYSTEMS FOR VES SURVEYS	Fig. 3

magnetic field. The spinning protons then generate a small signal in the same coil used to polarize them. This signal is directly proportional to the magnetic field intensity by the proportionality constant known as the gyromagnetic ratio. The precessional frequency is then measured by a digital counter as the absolute value of the earth's magnetic field intensity with an accuracy of 0.1 gammas.

The presence of metallic items in the near surface creates magnetic anomalies in the earth's magnetic field. The location and sensitivity of the magnetic sensors becomes paramount for detection of these metallic items. If the sensor is placed too close to the items, the magnetic anomaly may overwhelm the ability of the sensor to obtain a reading. By the same logic, if the sensor is too far away, the magnetic anomaly may not be large enough to affect the sensor.

The magnetometer used was equipped with a gradiometer option allowing two field readings at different heights and a gradient reading based on the two readings obtained. The unit makes a measurement of the earth's total magnetic field intensity and displays the result to an accuracy of 0.1 gammas. The reading is automatically stored along with the day, time of day, line number, and reading number in the digital memory. The data are then retrieved at the end of the day by transferring them to a computer through the computer's communications port.

The magnetic survey was conducted on a grid with a north-south spacing of 30 feet and an east-west spacing of 15 feet. Prior to beginning the survey, a base station point was established in an area with no known underground or overhead obstructions. Each day of the magnetic survey began and ended with a base station reading for use in removal of diurnal variations. Every 45 to 60 minutes during the survey, a base reading was also obtained for removal of diurnal variations throughout the survey day.

3.5 METAL DETECTOR

Metal detector surveys were conducted at locations of interest at the 881 Hillside area, including conductivity and magnetic anomalies, the reported locations of SWMUs, and cultural features such as buried pipelines or cables. The primary purpose of the survey was to define the areal extent of metallic cultural features such as Western Slope Gas Company's underground natural gas lines and the outfall pipelines at SWMU 106 and 107. The surveys were also to define, if possible, the presence of metallic items at conductivity and magnetic anomalies. A White's Treasuremaster TM600 Series 2 metal detector was used to conduct the survey.

A metal detector operates on a principle similar to a magnetometer. Both instruments measure the earth's magnetic field intensity with the principal difference being that the metal detector is adjusted to be in-phase with remnant magnetization present in the earth's magnetic field. Any magnetic anomaly with sufficient amplitude to create an out-of-phase response in the metal detector is detected. The in-phase adjustment allows the instrument to look at coarse measurements of the earth's magnetic field typically on the order of 10,000 gammas. Due to the nearness of the sensor to the items in question, significant changes in the magnetic field intensity can be sensed. Metal detectors are used exclusively to locate buried underground utilities and metallic items. They are not used to define subsurface conditions as magnetometers are used.

The TM600 is a two-coil unit with electronic nulling controls, sensitivity controls and a ground reject control. The ground reject control allows the unit to automatically adjust to eliminate false responses due to changing ground conditions, primarily from the mineral magnetite and its associated minerals. A multi-purpose, sensitivity meter is used to monitor the received target signals and a built-in speaker produces a tone which is proportional to the signal received.

Once an area of interest was identified, a grid with nodes spaced on the order of 5 to 10 feet was identified over the area. Two passes were made over the area in question at 90° to one another. This resulted in pinpointing the item in question and aided in defining the areal extent. Upon location of the item, a pin flag was placed to mark the areal extent in the field of the signal from the metal detector. These areas were marked as areas to be avoided during subsequent intrusive activities (e.g., drilling).

SECTION 4

DATA REDUCTION

4.1 ELECTROMAGNETIC CONDUCTIVITY

Conductivity and magnetometry data were processed on WESTON's Univac 1160 mainframe, Tektronix 4014 terminal and Tektronix 4663 plotter, with a CPS-1 contouring program. Contour intervals used for plotting conductivity and magnetometry data were 10 mmho/m and 50,000 gamma/m, respectively. These intervals were chosen to show trends in areas of subtle changes, while maintaining distinction in areas of contrasting data.

The CPS-1 program contours data by dividing each grid cell into intermediate sub-cells. An intermediate grid value is then computed as the average of the four corner values and located at the center of the sub-cell with diagonals to each corner. The intersections of the contour locus with the sides and temporarily computed diagonals are determined using inverse linear interpolation. The process continues until each chosen contour interval is completed.

4.2 RESISTIVITY

VES data were analyzed using one-dimensional modeling. One-dimensional modelling assumes that the earth in the vicinity of the VES survey can be represented by a series of flat-lying layers, each with a different electrical resistivity. This interpretation gives accurate results if certain criteria are met:

- the geologic structure to be located has a significantly different resistivity than its background;
- the lateral extent of these structures must be larger than their depth; and

- the layers must be relatively thick compared with their depth.

The interpretations were done using an automatic inverse modeling computer program initially developed by Dr. Adel A.R. Zodhy of the Water Resource Division, U.S. Geological Survey, in July 1980 and updated in August 1986. The computer program begins with a best-fit estimation based on Ghosh coefficients and tentatively converges to the geoelectric model which gives the least sum of squared residuals for the field data. The program then generates layer thicknesses, depths and resistivities.

For geologic environments such as that at the 881 Hillside area, where more than four layers are present and the layers are not flat-lying, lateral interferences affect calculations for both the layer thicknesses and layer resistivities. Wherever the lateral difference error exceeds 33%, the data were smoothed to reduce the error as much as possible and then were analyzed. The smoothing technique used consists of digitizing the data curves by reducing the high and low resistivity spikes in the field data prior to analysis for layer thickness and layer resistivities.

4.3 MAGNETOMETRY

Interpretation of the magnetic data consisted of three phases. The first phase removed diurnal variations in the earth's magnetic field from the field data using a linear interpolation method. The field data were also checked for regional gradient effects. Due to the small size of the 881 Hillside area, this was not a problem. The second phase generated the gradient data from the field data by dividing the difference between top and bottom sensors by the distance between sensors. The third phase developed computer generated contour plots of equal magnetic intensity called isogams.

The contour plots, as discussed in Section 4.1, were then compared to the electromagnetic survey for interpretation. No analytical modeling of the data was done to determine either shape or depth variables nor any geologic modeling to develop a stratigraphic model. All interpretation was based on a visual comparison of the contour plots with published magnetic curves of simple geologic models to determine whether the anomaly was attributable to geologic conditions or cultural interferences.

4.4 METAL DETECTOR

No data interpretation was required for the metal detector survey. Areas of buried metallic items were located in the field and marked with pin flags.

SECTION 5

SURVEY RESULTS

5.1 ELECTROMAGNETIC CONDUCTIVITY

EM data values show a general increase in conductivity from the top of the 881 Hillside area to the lower areas of the slope from 40 to 70 mmhus/m This probably results from changes in soil moisture content with distance down the slope. Examination of contour plots (Appendix B-1) of the electromagnetic data shows several areas of anomalous conductivity which are not readily explainable by the occurrence of cultural interferences. The approximate locations, based on the Rocky Flats grid system, of the anomalous conductivity values for each instrument are as follows and presented on Figure 2.

EM-34 Vertical		EM-34 Horizontal		EM-31	
N-34760	E-20740	N-34760	E-20740	N-34750	E-20680
--------	--------	--------	--------	N-34750	E-20830
N-34820	E-21100	N-34820	E-21100	N-34810	E-21130
--------	--------	N-34940	E-21280	--------	--------
--------	--------	--------	--------	N-34975	E-21640
N-35120	E-21280	--------	--------	--------	--------
--------	--------	--------	--------	N-35665	N-22060

The above data show a good correlation between anomalies detected with the EM-34-3 in horizontal and vertical dipole orientations. There is less correlation between EM-34-3 and EM-31 anomalies. This difference is the result of varying depths of penetration and intercoil spacing of the instruments. The EM-31 is more sensitive to small conductors than is the EM-34-3, but also has a more shallow depth of penetration. The instruments are therefore measuring conductivity changes over different intervals and are not expected to produce duplicate data.

The conductivity anomaly located near grid point N-35120, E-21280 is located in a low-lying area off the end of SWMU-107, extending laterally across SWMU-106. The shape of this anomaly suggests the presence of a trench at this location. An area of anomalously low conductivity values identified near grid point N-34760, E-20740 appears in the field to be debris (possibly asphalt) which has been deposited on the slope. This may represent the location of fire debris which was apparently dumped on the site and has been identified as SWMU-130. Potential explanations of other anomalies are unknown. Subsurface sampling planned for the 881 Hillside area may provide additional explanations. Results of the drilling program will be included in the remedial investiation report.

5.2 RESISTIVITY

The results of the VES surveys are presented as resistivity models in Appendix B-3. The VES surveys were then analyzed for stratigraphic interpretations as geoelectric models. A geoelectric model calculates a resistivity value for each a-spacing (electrode spacing). Stratification of the geoelectric model was based on changes of resistivity at each a-spacing. The changes were grouped together and the simple average of the resistivities was assigned to the group. Actual stratigraphic changes may not correspond to the geoelectric changes due to the averaging effect of the model.

At VES-1 (Figure 3-1), two highly resistive zones appear at the surface, corresponding to compacted fill with construction debris and compacted soil due to the area's usage as a storage facility for various on-site contractors. Below 2.2 meters (7 feet), the resistivity is 415 ohm-meters, normal for dry, silty and sandy gravel. The value of 640 ohm-meters may represent dry sandstone bedrock. Below this layer at a depth of 8.8 meters (28.7 feet), a value of 110 ohm-meters may result from the presence of wet claystone bedrock. The lower than normal resistivity values may indicate that claystone bedrock contains a high percentage of clay with a high cation exchange capacity.

The survey at VES-2 (Figure 3-2) indicated a layer approximately 2 feet thick with a resistivity of 260 ohm-meters representing colluvium. This layer overlies a stratum with a resistivity of 210 ohm-meters and a thickness of 7.4 feet likely composed of a slightly moist gravel. This stratum is underlain by a layer with a resistivity of 275 ohm-meters most likely representing a weathered bedrock composed of interbedded sandstone and claystone. Two additional layers were found below the weathered bedrock stratum with resistivities of 350 and 180 ohm-meters. These resistivities may result from a change in bedrock from a predominantly dry sandstone bedrock to a claystone and sandstone bedrock sequence.

VES-3 (Figure 3-3) exhibited a similar response to VES-2 with the exception of the surface layer. The resistivity of the surface layers, 895 and 580 ohm-meters, was higher than the surface layer at VES-2. These layers probably represent very dry colluvium with an increase in moisture content at depth. Below these strata, the geoelectric model for VES-3 was approximately the same as that of VES-2.

Both VES-4 and VES-6 (Figures 3-4 and 3-6) had similar responses to one another. VES-4 had a greater thickness of resistive layers probably representing colluvium and gravel strata than did VES-6 (9 and 2 meters, respectively). The bedrock resistivities for both surveys ranged from 105 ohm-meters to 390 ohm-meters. This was interpreted as claystone bedrock overlying sandstone bedrock. During analysis of the geoelectric models for these survey points, a thin, highly conductive layer was encountered at the top of the bedrock surface. This layer was tentatively identified as a possible perched water condition overlying the bedrock. The analytical model ignored this due to the model's theoretical basis which assumes the unit to be relatively thick compared to its depth.

VES-5 and VES-8 (Figures 3-5 and 3-8) displayed responses similar to VES-4 and VES-6. In general, VES-5 and VES-8 had lower resistivities (90 to 420 ohm-meters) than VES-4 and VES-6. The explanation for this difference appears to be wetter conditions at VES-5 and VES-8 as observed in the field. A layer present beneath (>1 m deep) the surface colluvium layer at VES-8 had a lower than expected resistivity of 160 ohm-meters which was assumed to be the gravel stratum typically found below the colluvium. This lower resistance appears to be the result of saturated conditions within the gravel layer.

At VES-7 (Figure 3-7), a change in resistivity at a depth of less than one meter within the assumed vadose zone appears to be a colluvium strata overlying a gravel stratum. Within the gravel stratum, a layer of reduced resistivity probably indicates the saturated zone. The resistivity values below the assumed saturated gravel stratum are similar to those encountered elsewhere. The values are typical of a claystone and sandstone interbedded sequence having resistivity values on the order of 170 to 200 ohm-meters and a claystone sequence having resistivities on the order of 90 to 130 ohm-meters.

VES-9 (Figure 3-9) was located based on the reported location of SWMU 104. As shown on Figure 3-9, significant resistivity changes occur in the upper 15 feet of the geoelectric model. A distinctive lower resistivity (270 ohm-meters) occurs between two resistivity values generally associated with the gravel stratum. This may result from the presence of a stratum of conductive material (e.g., contaminants) different from the gravel stratum. Below this sequence of resistivity changes, resistivity values typical of claystone and sandstone bedrock were found.

5.3 MAGNETOMETRY

Two general anomalous areas were detected during the magnetic survey, as shown on the contour plot presented in Appendix B-2. The first anomalous area was the southwestern section of the 881 Hillside area, south of Building 881. Numerous anomalous highs and lows, ranging from 45,000 to -30,000 gammas/m, were noted in this area. The majority of these anomalies are due to cultural interferences including disturbed ground, Western Slope Gas Company's natural gas pipelines (both the abandoned and active lines), culverts and other structures placed by Rocky Flats personnel to reduce soil erosion, and underground utility lines.

There are anomalies which are not related to cultural features. Four of the magnetic anomalies identified on the southwestern section of the 881 Hillside area corresponded to conductivity anomalies defined during the electromagnetic conductivity survey. The magnetic anomalies corresponding to the conductivity anomalies are located at the following grid points:

Magnetic Anomalies Corresponding to Conductivity Anomalies	
N-34750	E-20830
N-34760	E-20740
N-34750	E-20680
N-34820	E-21100

It is thought that the anomalies located at the above locations are the result of large concentrations of metallic objects which have been deposited on the site.

The second general anomalous area was along the top of the north ridge of the 881 Hillside area, east of Building 881. Numerous anomalous highs and lows, ranging from 45,000 to 30,000 gammas/m, were noted in this area. Examination of the top of the 881 Hillside shows extensive amounts of metal debris which has been deposited over the years. Due to magnetic noise in this area, no meaningful data interpretation was possible.

Both of the two anomalous areas are located in areas with extensive cultural interference. To more accurately define these areas, soil borings and ground-water monitoring wells will be installed. Results of the drilling investigation will be included in the remedial investigation report.

5.4 METAL DETECTOR

The metal detector surveys in the southwestern section of the 881 Hillside area consisted of investigating the reported locations of SWMUs 102, 103, 104, 106, 107, 130, and 177, various cultural interferences, and conductivity and magnetic anomalies. No buried metallic items were encountered at SWMUs 102, 103, 104, 106, and 107. The overhead lines and chain link fence at SWMU-105 created sufficient magnetic noise that no readings were possible. Cultural interferences included Western Slope Gas Company's natural gas pipeline which was located in the field and pin flagged for reference and a second Western Slope Gas Company natural gas pipeline which was located south of the present line, but terminated at the interceptor ditch further south of Building 881.

Additional cultural interferences located during the survey included the outfall pipe (SWMU 107) from Building 881 to the holding pond and from the holding pond to the interceptor ditch. Another pipeline (SWMU 106) was located west of this pipe, but could not be traced further than 10 feet north of where it is exposed in the interceptor ditch. All structures were located in the field and marked with pin flags for future reference.

The reported location of SWMU 104 and the northern ridge east of Building 881 were investigated. No metallic items were detected at the reported location of SWMU 104. Metal detector response indicated that the top of the northern ridge holds large quantities of buried metallic items. A number of these items were exposed at the surface and consisted of reinforcing bars encased in concrete. The area contained such a large quantity of metallic items that the areal extent was defined in gross terms as the top of the northern ridge. South of the northern ridge, Western Slope Gas Company's existing natural gas pipeline was present. The pipeline was located in the field and marked with pin flags.

SECTION 6

CONCLUSIONS

Geophysical surveys of the 881 Hillside area of the Rocky Flats Plant were carried out in order to investigate and identify, as possible, the location of SWMUs, and to provide information about subsurface conditions upon which to plan subsequent portions of the RI/FS investigation. The data obtained resulted in the identification of areas of anomalous geophysical response to be investigated as specified in the CEARP IGMP/SSMP Sampling Plans. Anomalies or areas of anomalous geophysical response are defined by measured values differing from those within normal background range. The geophysical surveys, in conjunction with soil gas results, were used to plan areas for subsurface investigation, monitoring well installation, and groundwater sampling.

The locations of the apparent geophysical anomalies are identified on Figure 2. Anomalies were identified by electromagnetic and magnetic methods near the south ends of SWMUs 106 and 107, and off the southwest corner of SWMU 130. The cause of the anomalous readings obtained from these locations is unknown. However, the shape of the anomalies near SWMUs 106 and 107 suggest that a trench may be located at this position. The anomaly located off the southwest corner of SWMU 130 cannot be identified at this time. Individual electromagnetic anomalies, possibly resulting from buried fire debris, were also observed near the western and southern margins of SWMU 130. The locations of each of these anomalies has been compared to known cultural interferences. No apparent cultural interference could be identified as being responsible for these anomalies. Large areas of the northern and southwestern portions of the 881 Hillside area contained sufficient magnetic debris to make meaningful data interpretation impossible. The magnetic anomalies identified on Figure 2 therefore represent areas of anomalous readings which correlate with electromagnetic anomalies. Vertical Electrical Soundings were completed at nine survey points in order to provide information on site stratigraphy. The results of each of the above geophysical surveys are discussed in detail in Section 5.

Quality Control data for each instrument were collected as specified in the CEARP Quality Assurance Plan. The resulting data indicates that instrument functions and operating procedures were properly conducted. Details of quality control procedures are provided in Section 7.

SECTION 7

QUALITY CONTROL

7.1 ELECTROMAGNETICS

The EM-31 and EM-34-3 instruments were operated in accordance with the operating instructions provided by the manufacturer, Geonics, Ltd. In order to detect and correct for any drift of the instruments during the course of the surveys, base stations were designated at the beginning of each survey. Prior to beginning each day's survey, measurements were taken at the base station and compared with previous readings. Base station readings were repeated at frequent intervals throughout the survey day. Other instrument functions checked during base station visits included meter null, sensitivity checks, and battery charge. Quality control data from each instrument is provided in Table I.

7.2 RESISTIVITY

The VES system was operated in accordance with the operating instructions provided by the manufacturer, Bison Instruments, Inc. The system was checked for drift at the base station established for the electromagnetic conductivity instruments (N-36200, E-22300). The system was set up and two sets of readings were obtained. The two sets of readings were always within +/- 5% of one another.

Upon completion of each VES survey, the data were cross-checked according to procedures provided by the manufacturer. Millivolt readings were obtained from the five array patterns (see Figure 3) for each a-spacing. The cross checks were as follows:

- A>C>D1;
- D1~D2; and
- A-C~B

TABLE I

QUALITY CONTROL DATA

Instrument: EM-34-3

Base Station: N36200, E22300

Date	Time	Vertical Dipole	Horizontal Dipole	Battery	Null
3/25/87	1310	40	38	OK	OK
3/25/87	1625	37	38	OK	OFF 1 mmho/m
3/26/87	0900	38	38	OK	OK
3/26/87	1230	40	38	OK	OFF 1 mmho/m
3/26/87	1547	40	38	OK	OK
3/30/87	1015	40	38	OK	OK
3/30/87	1320	38	38	OK	OK
3/31/87	0850	39	38	OK	OK
3/31/87	1150	39	37	OK	OK
3/31/87	1603	37	37	OK	OK
4/1/87	0850	37	37	OK	OK
4/1/87	1225	36	39	OK	OK
4/1/87	1520	12	12	OK	OFF 1 mmho/m
4/1/87	1525	38	36	OK	READJUSTED
4/2/87	1250	40	38	OK	OK
4/2/87	1500	37	34	OK	OK

Instrument: EM-31

Base Station: N36200, E22300

Date	Time	Reading	Battery	Null
4/8/87	1220	32	OK	OK
4/8/87	1530	32	OK	OK
4/10/87	0900	34	OK	OK
4/13/87	0920	34	OK	OK
4/13/87	1245	32	OK	OK
4/13/87	1520	32	OK	OK
4/14/87	0810	32	OK	OK
4/14/87	1255	32	OK	OK
4/14/87	1620	31	OK	OK
4/15/87	0810	31	OK	OK
4/15/87	1245	31	OK	OK
4/15/87	1620	30	OK	OK
4/16/87	0830	31	OK	OK
4/16/87	1230	32	OK	OK

No repeat readings were required for any of the nine VES survey points. A battery check was also conducted each morning and at the end of the survey day. When the battery indicators approached 11.4 volts, the batteries were recharged overnight.

7.3 MAGNETOMETRY

The magnetometer was operated in accordance with the operating instructions provided by the manufacturer, EG&G Geometrics. Prior to beginning the magnetic survey, a swing test was conducted at the base station to detect any directional sensitivity of the sensor. Each swing test consists of three sets of four readings, each taken with the sensor oriented at 90^{o} from the other. If direction sensitivities were detected, they were corrected by scrubbing the sensors with detergent and water. The sensors were then retested. The results of the swing tests are presented below:

SWING TEST RESULTS

Swing Test No.	Date	Swing	North (gammas)	East (gammas)	South (gammas)	West (gammas)
I	3-30-87	1	54,560.7	54,562.3	54,561.7	54,561.0
		2	54,564.3	54,560.7	54,562.7	54,561.3
		3	54,563.9	54,560.4	54,560.4	54,560.3
II	3-30-87	1	54,558.1	54,557.9	54,557.9	54,558.1
		2	54,558.2	54,558.2	54,558.1	54,558.1
		3	54,558.3	54,558.3	54,558.4	54,558.4
III	4-8-87	1	54,860.4	54,860.6	54,860.4	54,860.5
		2	54,861.0	54,860.9	54,860.8	54,860.5
		3	54,860.3	54,860.5	54,860.5	54,860.3

Notes: 1) Swing test #I failed

2) Swing test #II accepted

3) Swing test #III accepted

The magnetometer was held in a north-south direction with the operator standing to the west of the sensors in an attempt to standardize any effects the operator and mode of operation would have on the instruments. Batteries used in the instrument were industrial heavy-duty D-cell batteries with cardboard jackets to further reduce any effects to the instrument from metal clad batteries. The batteries were changed whenever the voltage indicator fell below 8.5 volts.

During the survey, base station readings were obtained at the beginning and end of the day and at every 45 to 60 minutes throughout the survey. The base station readings were used to remove diurnal effects of the earth's magnetic field from the field data. Two sequential readings were also taken at the base station at the beginning and end of the survey day. The sequential readings were obtained within three seconds of one another. If the readings differed by more than 0.1 gamma from one another, the readings were recorded in the field books. All sequential readings differed by less than 0.1 gammas.

The use of the digital memory in the magnetometer required that the beginning and ending stations along with the corresponding magnetometer readings be recorded at the start and finish of a traverse. Upon "downloading" of the magnetometer, these readings were cross-checked for accuracy. With the exception of an operator error, all data cross-checked satisfactorily.

7.4 METAL DETECTOR

The metal detector was operated in accordance with operating instructions by the manufacturer, White's, Inc. Each survey day began with adjusting the null controls and maximizing the sensitivity of the metal detector at the magnetometer base station. The instrument was continuously adjusted until the nulling controls were at a maximum. The sensitivity control was then adjusted to maximize the depth of signal reception. During the surveys, occasional minor adjustments were made to the ground reject control to fine-tune the instrument when changing ground conditions were encountered.

SECTION 8

REFERENCES

DOE, 1986f: "Resource Conservation and Recovery Act Part B--Operating Permit Application for USDOE Rocky Flats Plant, Hazardous and Radioactive Mixed Wastes," U.S. Department of Energy Unnumbered Report, November 1986.

DOE, 1987a: "Phase 2: Rocky Flats Plant Site-Specific Monitoring Plan (Work Plan for Performance of Remedial Investigations and Feasibility Studies for all High-Priority Sites)", U.S. Department of Energy Draft Report, February 1987.

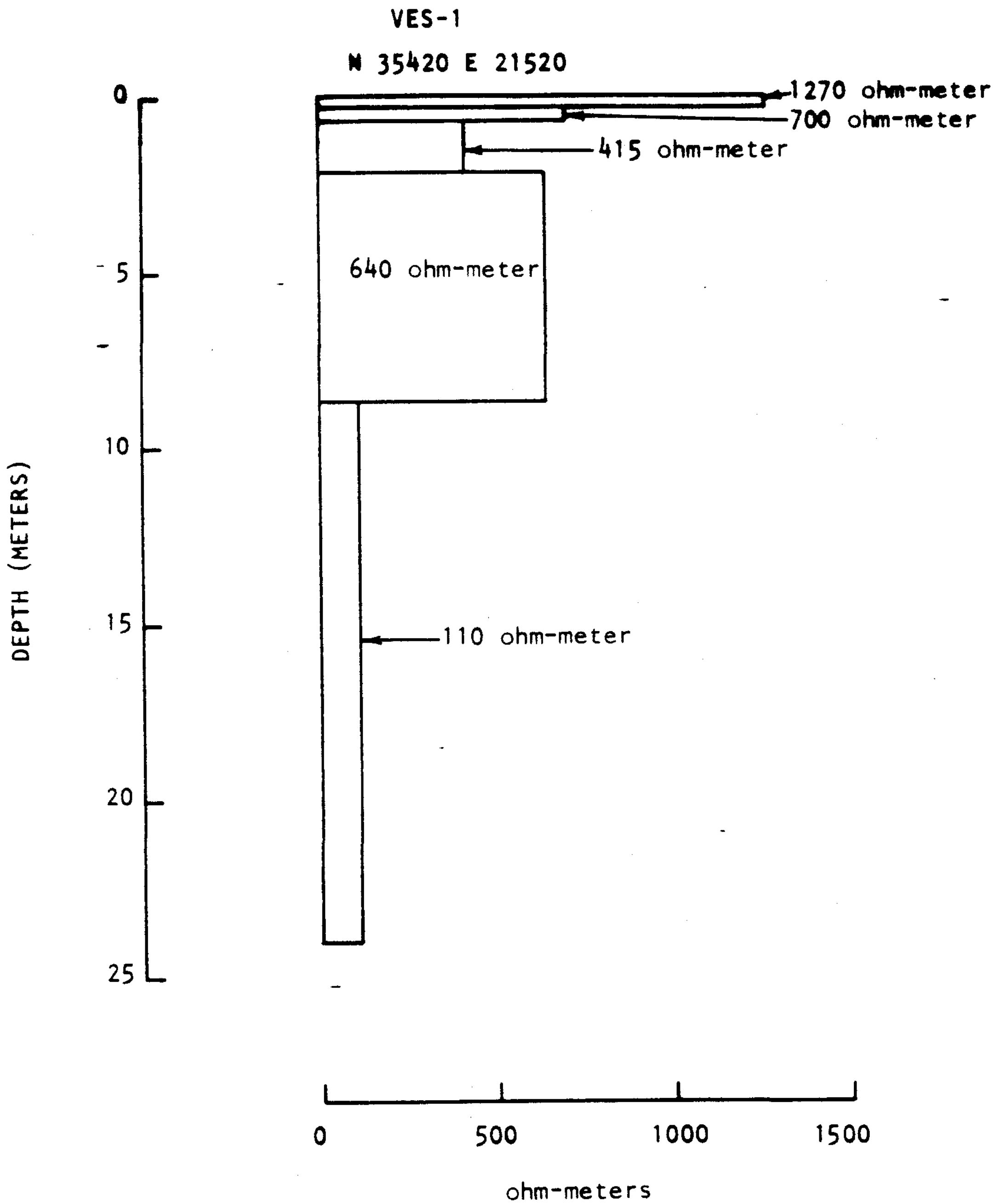
DOE, 1987b: "Phase 2: Rocky Flats Plant Installation Generic Monitoring Plan," U.S. Department of Energy Draft Report, February 1987.

Geonics, Ltd. (1980): "Electromagnetic Terrain Conductivity Measurement at Low Induction Numbers." Edited by J.D. McNeil, October 1980.

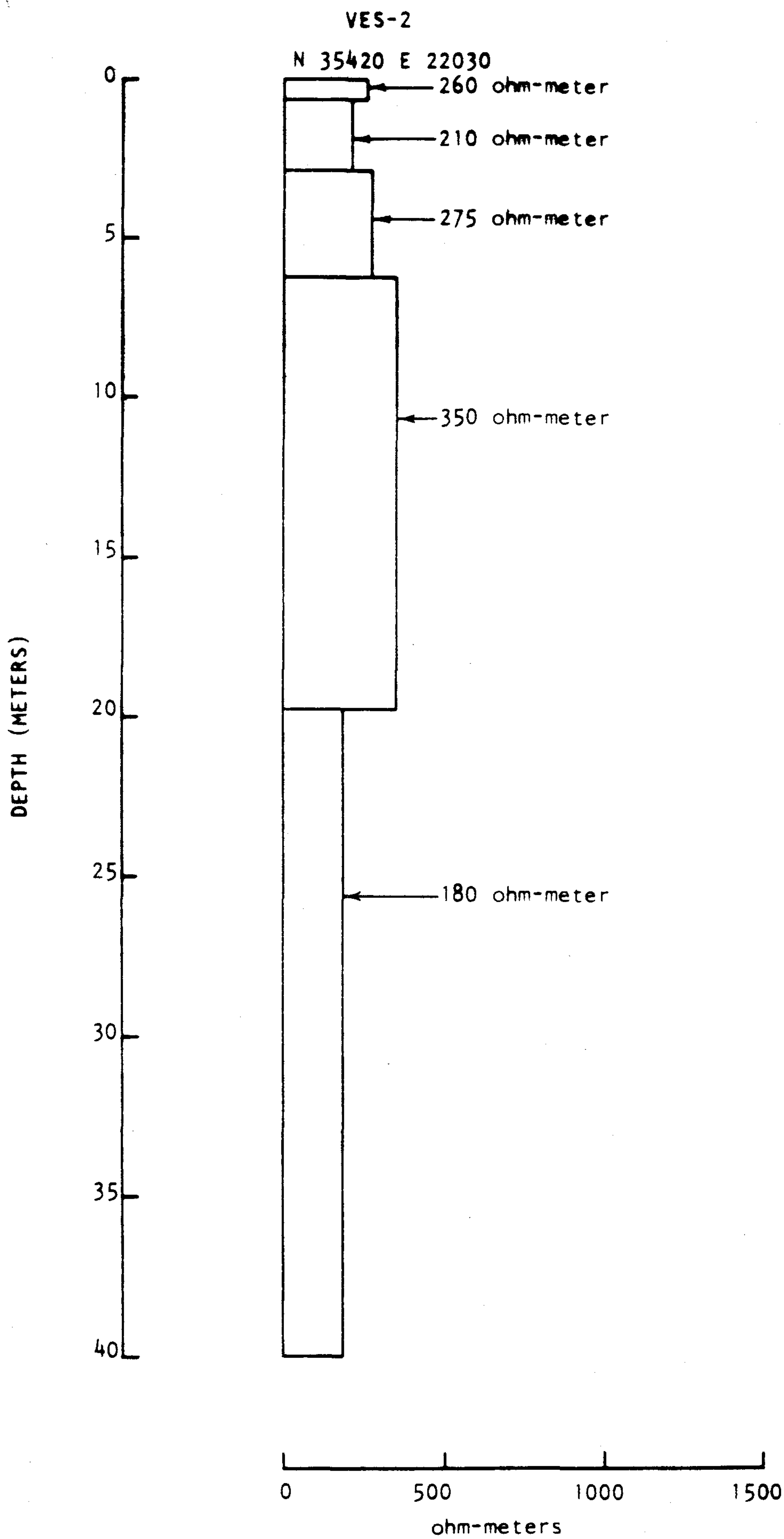
APPENDIX B-1

APPENDIX B-2

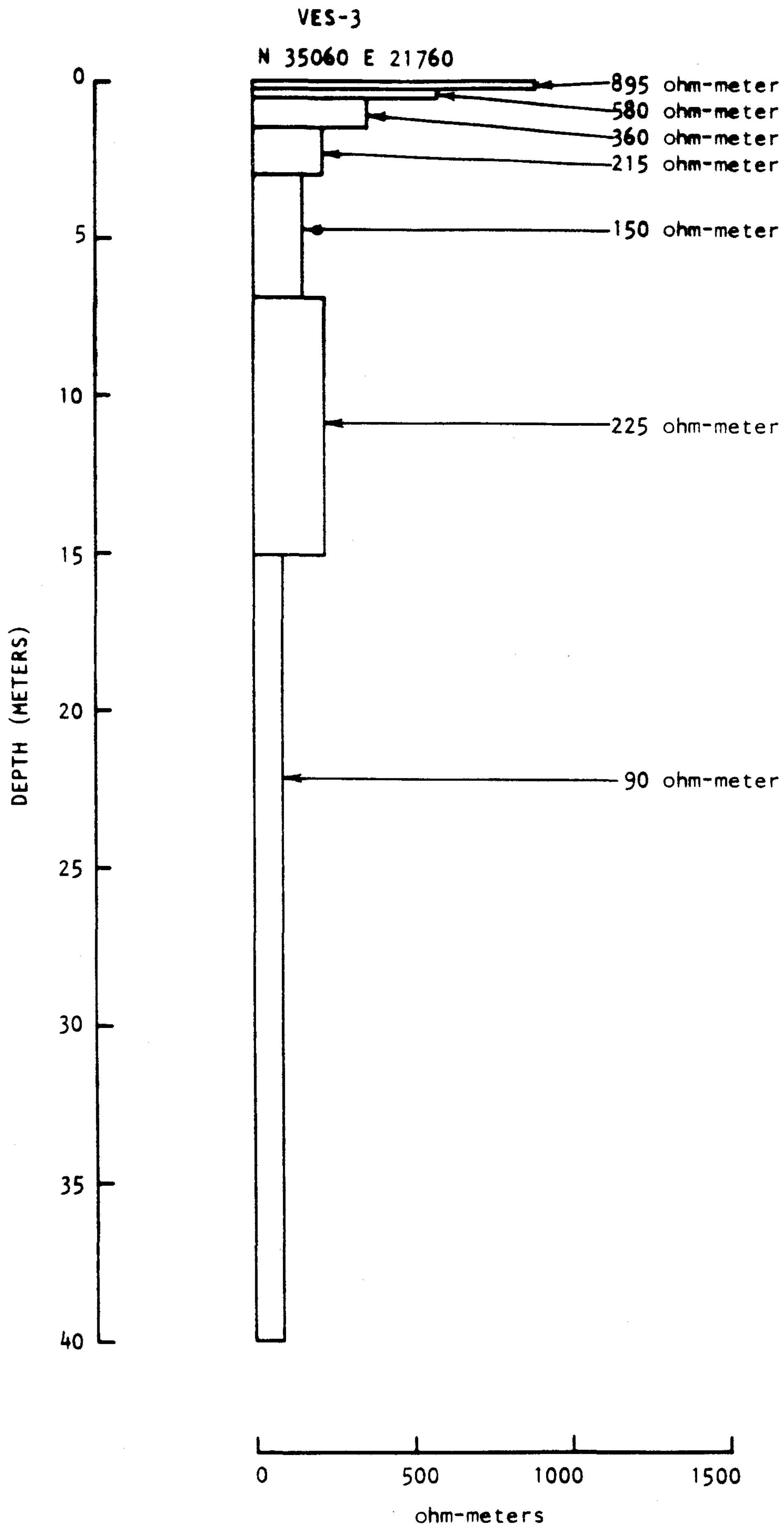
APPENDIX B-3



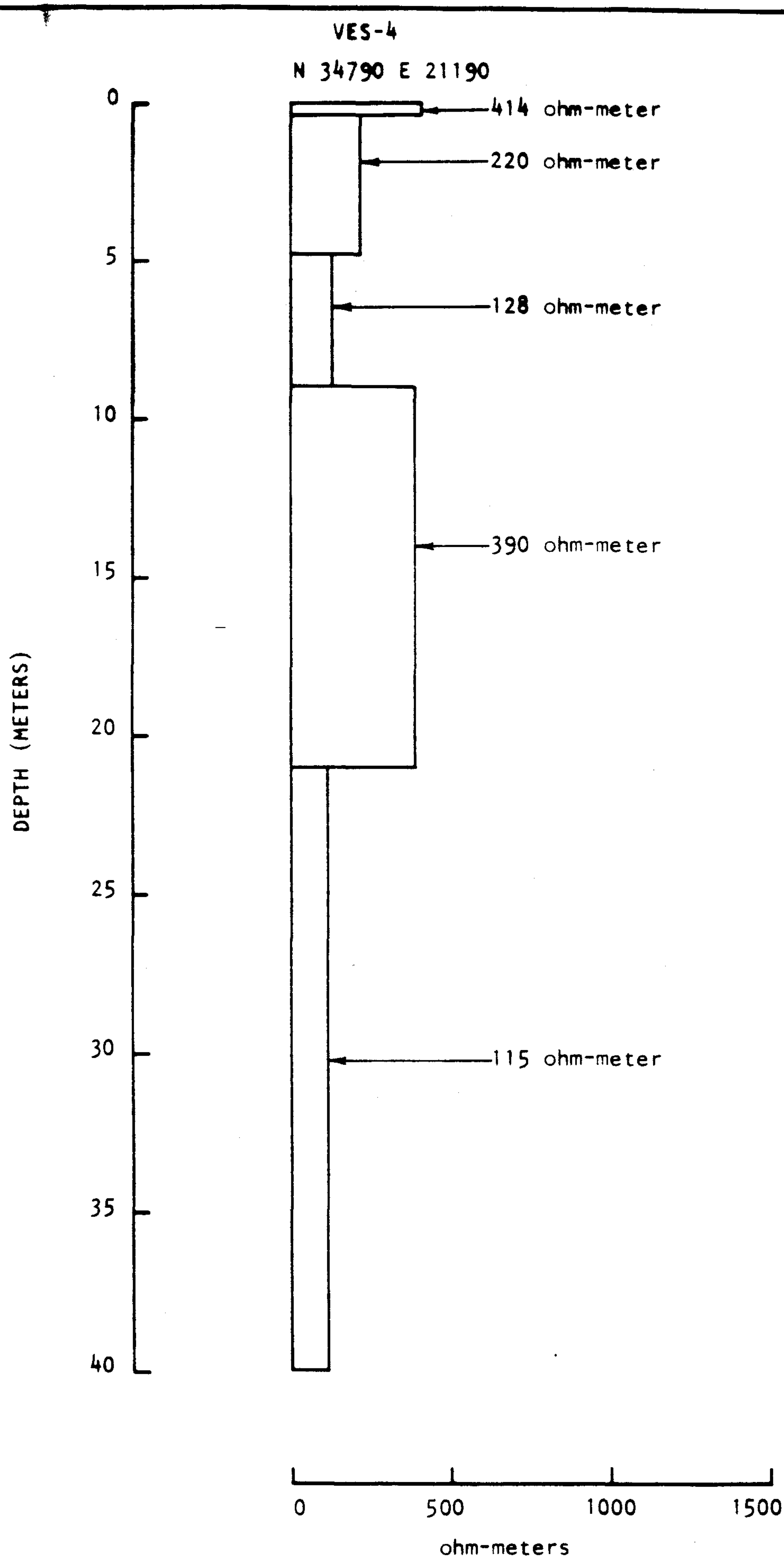
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-1	Fig. 3-1



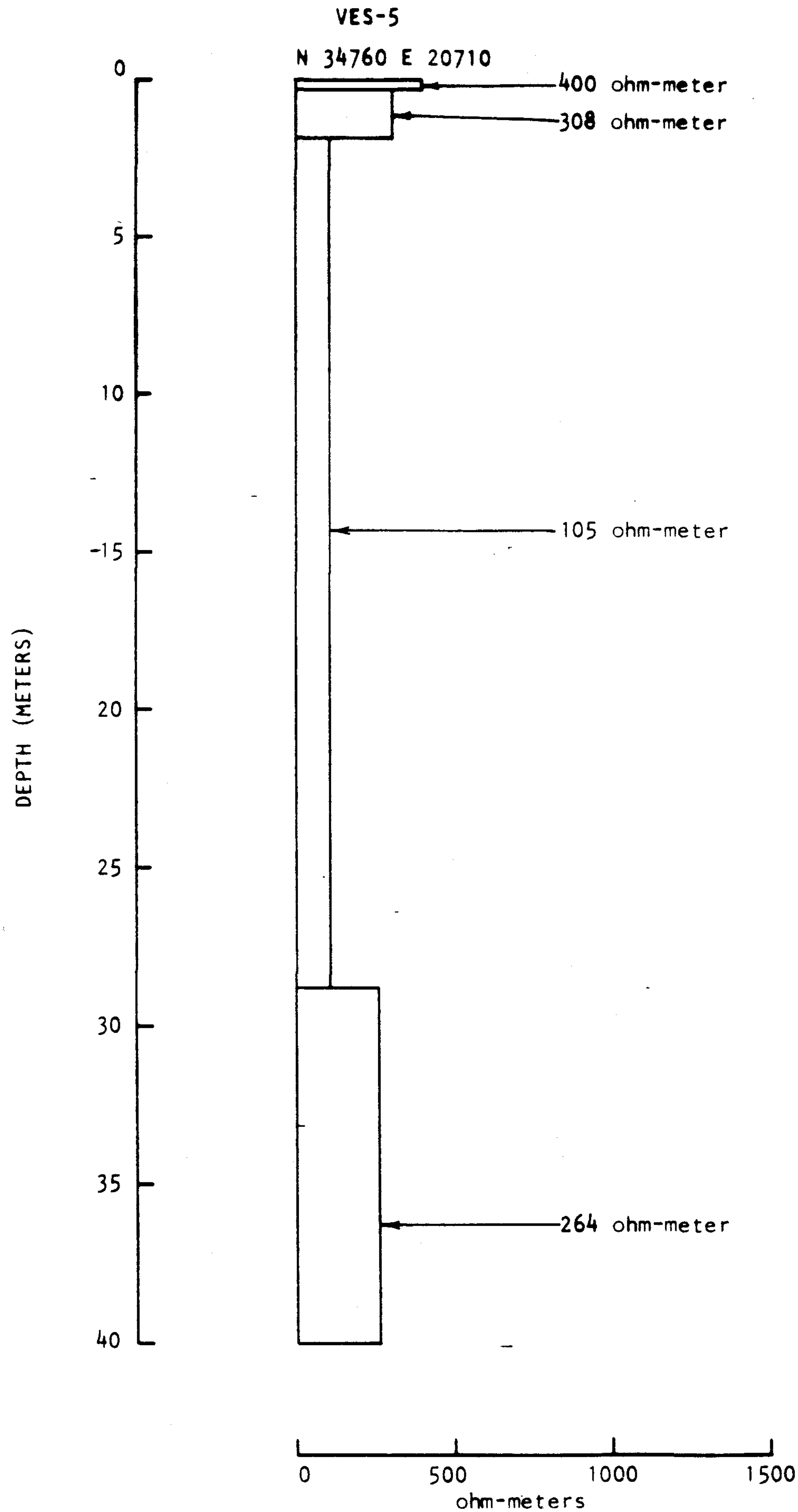
6 007 87	**Chen & Associates**	INVERSION RESULTS FOR VES-2	**Fig.** 3-2



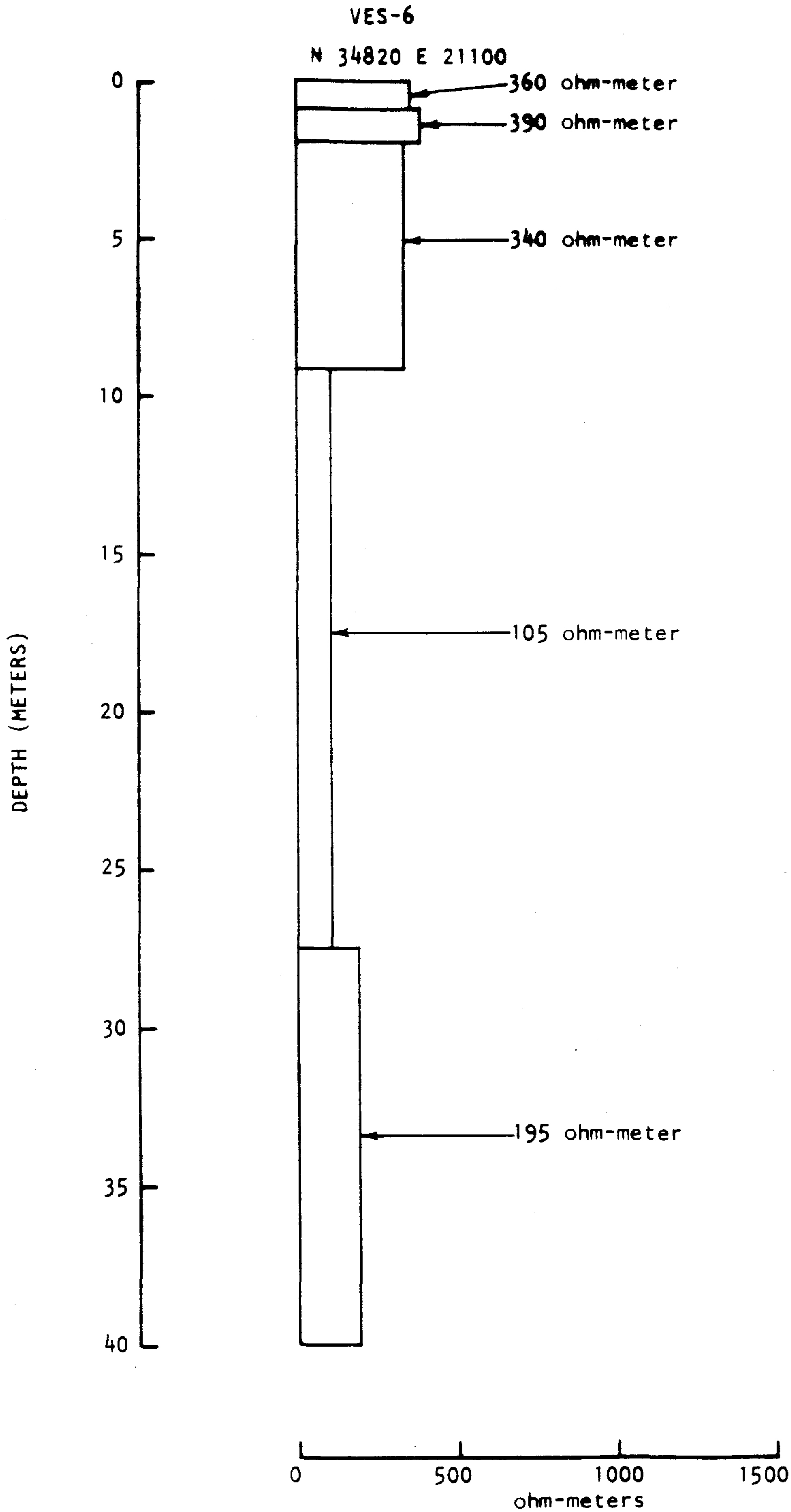
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-3	Fig. 3-3



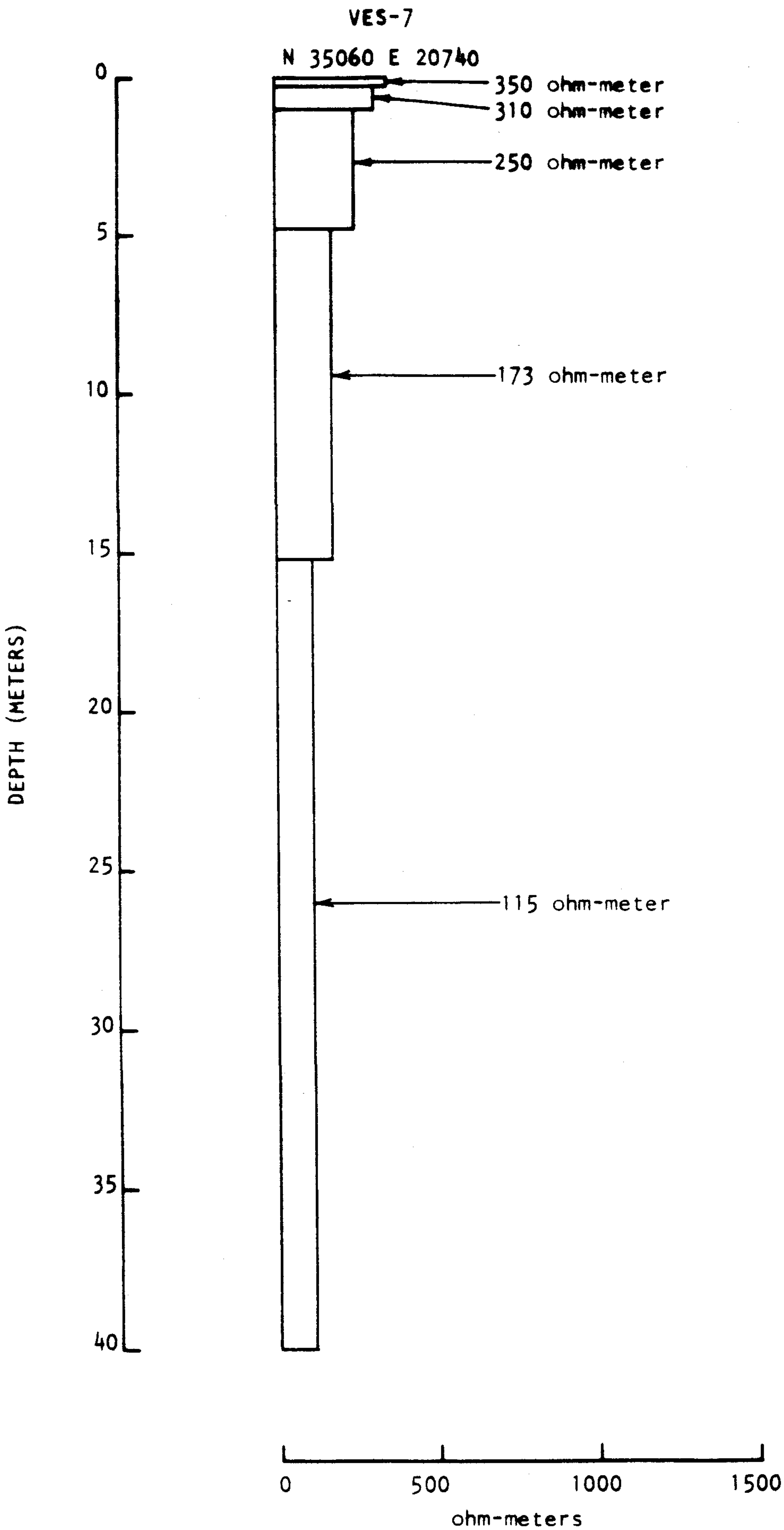
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-4	Fig. 3-4



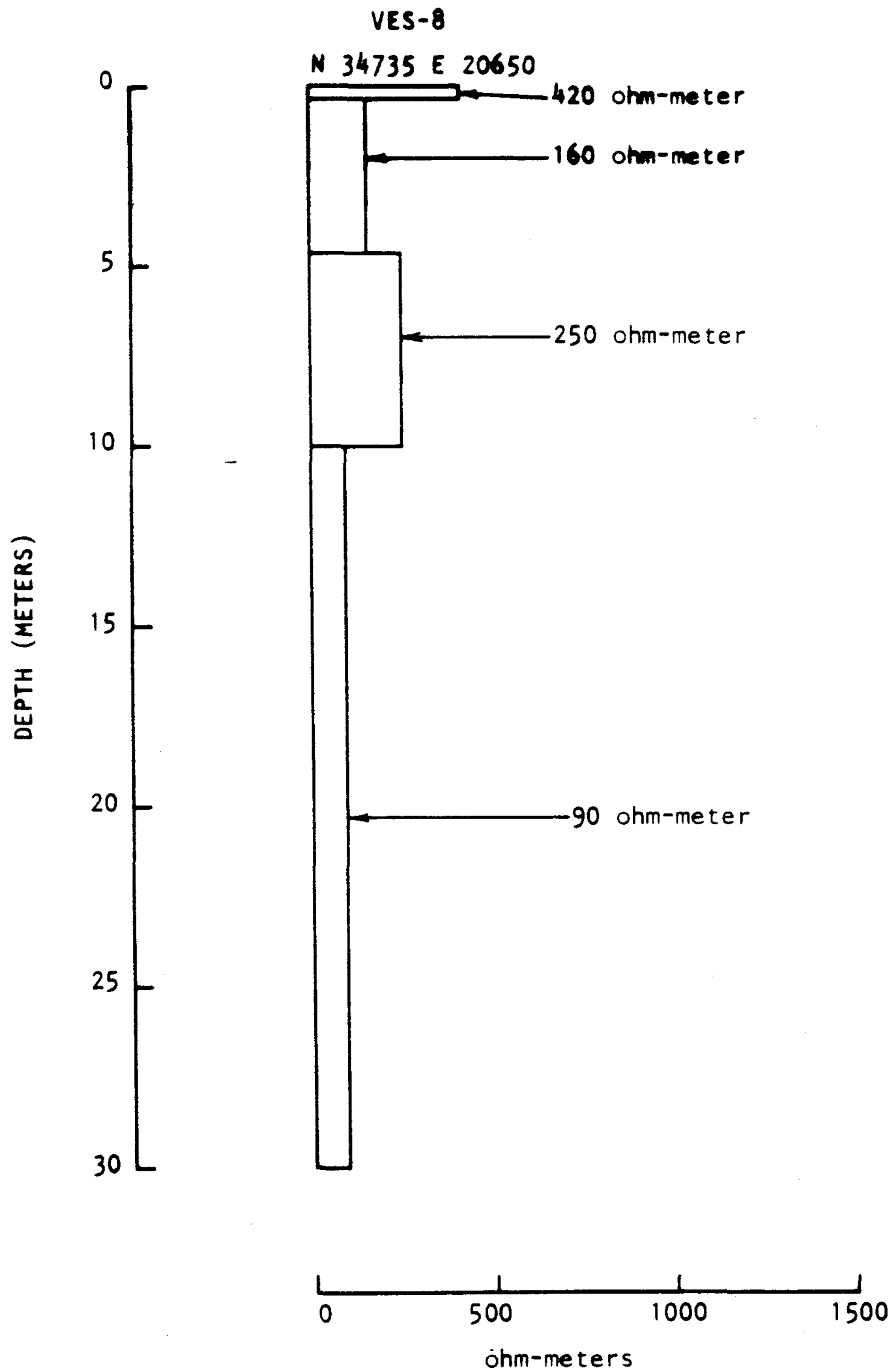
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-5	Fig. 3-5



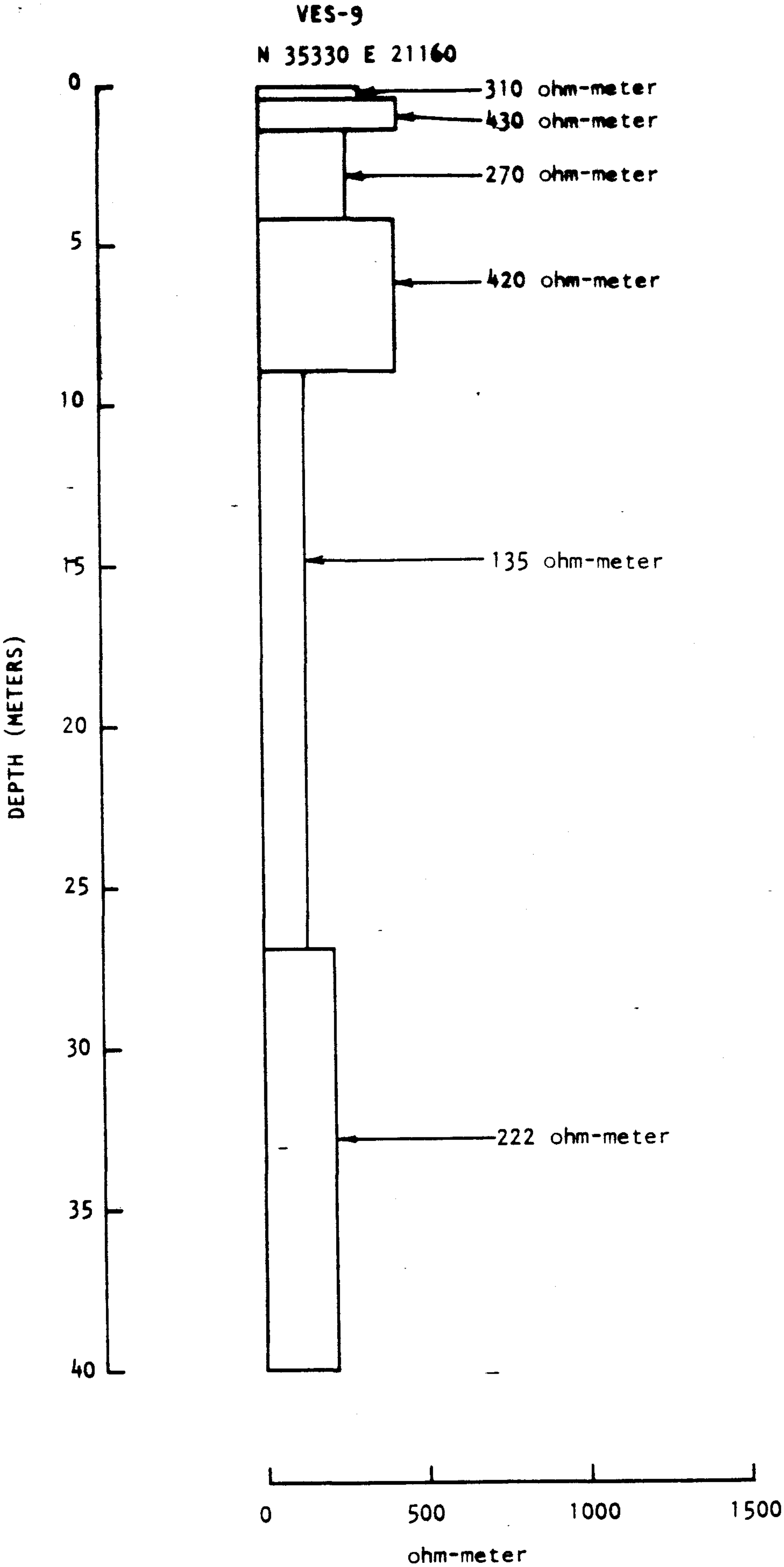
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-6	Fig. 3-6



6 007 87	**Chen & Associates**	INVERSION RESULTS FOR VES-7	Fig. 3-7



6 007 87	**Chen & Associates**	INVERSION RESULTS FOR VES-8	Fig. 3-8



6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-9	Fig. 3-9

Appendix C

APPENDIX C

SOIL GAS SURVEY

1.0 INTRODUCTION

A soil gas technique was used as a reconnaissance tool to locate and identify areas of subsurface organic contamination. This method provides an efficient, economical means by which trace quantities of subsurface organic contaminants can be detected on the ground surface. For the 881 Hillside Area remedial investigation, the objective of the work was to determine the presence and relative concentrations of 1,1-dichloroethene, 1,1,1-trichloroethane, carbon tetrachloride, trichloroethene, and tetrachloroethene in shallow soils. These volatile organic compounds are known to be present in the ground water associated with these areas, and the distribution of these compounds in shallow soils can be an indication of their lateral distribution in the ground water. Thus, the soil gas survey is used to provide a preliminary delineation of plume boundaries so that monitoring wells can be effectively placed to confirm contaminant plume locations. In the 881 Hillside Area, no carbon tetrachloride molecular counts were detected.

The RI Work Plan called for real time measurement of soil gas. Real time measurements are extracted by inserting a hollow conduit into the soil to a given depth and evacuating a predesignated volume of gas. After the system has been purged of any atmospheric air, a sample is extracted and analyzed, either on-site or in a remote laboratory. The advantage of this procedure is that data are, in general, available more quickly than time integrated methods. The disadvantages are the added equipment and cost required to do the sampling and analysis and a reduction in the mobility of the sampling vehicle. Another disadvantage is that real time methods increase the lower detection limit. For these reasons, it was decided to use Petrex's time integrated method.

Petrex's time integrated method employs activated carbon to collect the contaminants for a period of time specifically determined for the site to concentrate the contaminant to a level that might otherwise be undetectable. Time integration also alleviates any variations in the contaminant concentrations due to transient situations that might not reflect the true conditions (e.g., fluctuations in barometric pressure, rain percolating through the soil, and porosity differences in the soil). In addition, all equipment required to perform the sampling can be carried into the target area by two individuals. This reduces traffic in areas where heavy traffic might cause re-suspension of soil possibly contaminated with radioactive contaminants. Rather than mass per unit volume measurements that are the result of real time gas chromatographic analysis, the time integrated results are measured in terms of ion counts determined by mass spectrometry of heat-purged compounds from the activated carbon. A synopsis of the Petrex method is shown in Appendix C-1.

2.0 PROCEDURE

2.1 METHODS

The sample collector consists of a ferromagnetic wire coated with an activated carbon which is inserted into a resealable glass tube. A two-inch rod is driven approximately eighteen inches into the soil, and the sample collector is inserted into the resulting hole. Soil is then packed into the hole, covering the tube. Appendix C-2 contains the field instructions that were followed.

The optimal exposure period for volatile organic detection was established by positioning time calibration collectors that were removed at 7, 9, and 11 days, and subsequently analyzed. The analyses of these collectors indicated that soil gas flux was slow, and therefore a twenty-one day incubation period was established to maximize adsorption of soil gas compounds but allow completion of the work in the short time frame.

After twenty-one days the tubes were removed, and the carbon was analyzed for contaminants by Curie-Point mass spectrometry. The carbon is burned at the Curie-Point temperature of the ferromagnetic wire releasing and ionizing the adsorbed compounds. The ions are subsequently separated and identified in the mass spectrometer. Spectrographs representing total ion counts versus mass/charge were generated for each collector. These "fingerprints" allow computerized identification of individual species.

2.2 QUALITY ASSURANCE/QUALITY CONTROL

In order to document contaminant-free samples for emplacement and instrumental analysis, quality control procedures were strictly followed. Quality Assurance and Quality Control procedures are presented in Appendix C-3. For example, to assure contaminant-free samplers, the samplers are assembled in an inert atmosphere. Samplers are periodically removed from each batch and analyzed to detect any contamination. During mass spectral analysis, calibration and periodic background checks are routine.

Duplicate and field blank Quality Assurance (QA) samples were taken during the soil gas sampling operation. Sample locations are shown on Plate 4-2. All volatile organic contaminants listed in Section 1.0 were looked for in duplicate and field blank samples. Duplicate samples were taken by placing two wires into the same tube. Results of the duplicate samples for the area are presented in Table C-1. Ion counts of any volatile organic contaminants, if found, are also shown. Only tetrachloroethene (PCE) and trichloroethene (TCE) were found in QA samples. Field blanks are taken by installing sealed tubes next to an open tube. The field blank results are also presented in Table C-1.

2.3 SURVEY GRID

Rocky Flats Plant coordinates were surveyed and staked to establish a sixty-foot by sixty-foot grid for which samplers were to be placed at nodes every 120 feet. The RI Work Plan grid spacing for the soil gas stations (90 foot centers) was

TABLE C-1

SOIL GAS QUALITY ASSURANCE

SAMPLE LOCATION	DUPLICATE	BLANK
14	-----	0
17	-----	0
32	0:0	-----
50	PCE 965:209	-----
65	0:0	-----
93	0:0	-----
98	0:0	-----
101	0:0	-----
104	0:0	-----
107	0:0	-----
110	PCE 155:455	-----
114	0:0	-----
115	PCE 1,006:0	-----
116	PCE 968:1,271	-----
	TCE 0:352	
120	TCE 0:408	
128	TCE 107:322	
	PCE 176:306	
138	0:0	
174	0:0	
179	0:0	

determined to be inconsistent with Petrex's recommended alignment. Therefore, samplers were placed every 120 feet along a grid line using sixty-foot offsets for each successive grid line. This offset grid was designed so that adjacent grid lines are sampled at non-aligned stations, thus interrupting the orthoganol pattern of a uniform grid. One hundred and eight samplers were installed at the 881 Hillside Area.

2.4 PLUME MAP

A relative ion count intensity map was prepared for each organic vapor of interest. These relative intensities have been plotted to infer concentration gradients and source locations. Sample locations are shown on Plate 4-2, and data are presented on Plates 4-3 through 4-7. Due to drastic changes in ion count intensities over a small area, the plume maps were not contoured.

APPENDIX C-1

PETREX ENVIRONMENTAL ANALYSES

APPENDIX C-1
PETREX ENVIRONMENTAL ANALYSES

A description of the Petrex Soil Gas Technique for collection and identification of trace volatile organic compounds is presented below.

1. Collection - Activated carbon which is bonded to a ferromagnetic wire is placed in a glass tube and buried just below the soil surface. After a predetermined collection period (3-30 days), the tubes containing the carbon-bearing wires are retrieved, sealed and taken to the laboratory for mass spectrometric analysis.

2. Analysis - The organic gases adsorbed on the carbon are purged from the carbon, separated according to ion mass, counted, and a mass spectrum of masses from 29 to 240 is drawn.

3. Identification - These mass spectra are compared with mass spectra derived from known volatile organic compounds and the compounds are identified.

4. Derivation of relative total counts for mapping purposes - The relative ion count intensity (relative intensities) of the gases collected on various collectors are correlated with sample locations on a map of the survey area. These relative intensities are useful for inferring relative differences in the concentrations of the compounds in the soil or ground water, which can be used to help determine the direction of source areas and/or direction of movement of contamination.

NOTES OF CONSIDERATION:

1. These surface collections and analyses cannot be used to determine the depth to the source contaminants.

2. Because compounds can be differentiated by their spectra, analyses from the carbon collectors can be used to help differentiate multiple source areas.

3. Most areas have a natural background of trace emanations from naturally occurring compounds. The distinction of this background from contamination is facilitated by Petrex's examination of more than 50,000 of these spectra. All of these spectra are available from developed "spectra laboratory" for use in identification of compounds.

APPENDIX C-2

FIELD INSTRUCTIONS

APPENDIX C-2
FIELD INSTRUCTIONS

1) Dig sample location 10-12 inches deep and approximately 2-4 inches in diameter. Do not contaminate the soil. (Under asphalt or cement: 2-3' below base of asphalt or cement.)

2) Remove the cap and immediately place sampler (vertically with open end down) into sample location hole. The sampler tube must be at least two inches below ground surface. Immediately cover the sampler with soil.

3) Return the cap to one of the clean plastic bags provided.

4) Mark the sample location with flagging or other material. Note the sample location on a base map and enter information in a field notebook.

5) Retrieving samples (should be done at the recommended time intervals):

   (A) Remove the soil until tube is exposed.

   (B) Take a cap from sealed plastic bag. Check for blue teflon liner inside cap. If liner has fallen out, replace it.

   (C) Remove tube from the hole. If wire falls out of tube or if tube is broken, use tweezers to handle wire.

   (D) Wipe off the tube and threads thoroughly with a clean, dry cloth. If the tube threads and lip are not properly cleaned, the cap will not seal and the sample will become contaminated.

(E) Seal tube with cap, making sure the teflon liner is seated to tube lip.

(F) Place sticker on cap top and number. Number sequentially starting with 1. Use only numbers to identify samples. For two wire samplers, use two consecutive numbers. Please underline all numbers for easy identification. Do not duplicate cap numbers.

(G) Record number or numbers of sampler corresponding to location on base map and field notebook.

(H) Do not place tape, sticker, or glue on glass tube. Stickers provided will adhere if placed on dry cap.

6) When packaging exposed tubes, please do not use Styrofoam or popcorn packaging as this can potentially introduce a contaminant. Enclose tubes in two plastic bags as provided and wrap each package tightly with bubble wrap.

The contents of this package should be as follows:

_______ Single Wire Tubes

_______ Double Wire Tubes

-- To be placed in the survey area as if they were single wire tubes. These samples are to be used internally as QC and calibration samples.

_______ Field Blanks

-- To be placed in the survey area with the caps still on, one blank placed each day until all blanks are used or place leftover blanks on last field day.

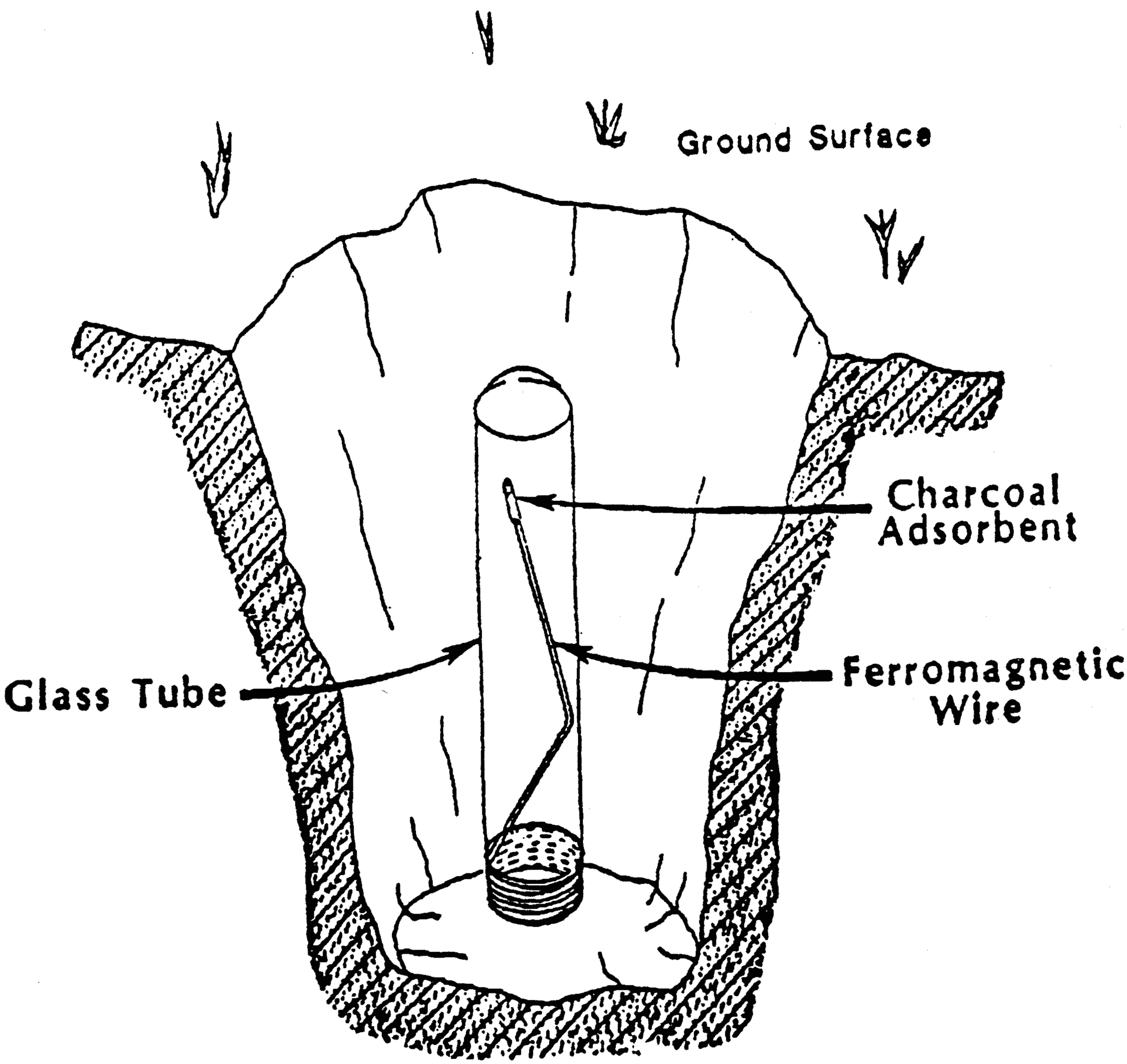
_______ Time Test

-- To be placed over an area of suspected volatile compounds. When returning these samples to Petrex, please label them with Project # _____________.

_______ Cap Labels

**** CAUTION ****

The most critical aspect of collector placement is not to expose the collector to contaminants. Smoking, exhaust fumes, etc., will contaminate the collector. Hands must be kept free of organics, including insect repellant, sunblock, gasoline, motor oil, cosmetics, etc. The lip and inside of the tubes, caps, and cap liners must not contact any contaminants.


Ground Surface
Charcoal
Adsorbent
Glass Tube
Ferromagnetic
Wire

APPENDIX C-3

PETREX QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

APPENDIX C-3
PETREX QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

Wire Preparation

1. Sampler materials are processed through thermo-chemical cleaning procedures.

2. Adsorption wires (after construction) are cleaned by heating to 358 degrees C in a high vacuum system.

3. Wires are packed under an inert atmosphere in respective vials.

4. One collector out of every thirty is checked for contamination by mass spectrometry. Based on the results, the group of thirty collectors is approved for release into the field.

Sampler Shipment and Field Handling

1. Five percent transportation blanks are included with each shipment. Transportation blanks (2.5% of total) samplers are stored until analysis with the field samplers.

Mass Spectrometer Tuning

1. An Extranuclear Quadrupole Mass Spectrometer is used for collector analysis. Mass assignment and resolution are manually adjusted using a Perfluorotributylamine (PFTBA) standard. The mass offset value is entered into the computer, followed by comparisons of a computer-generated PFTBA

spectrum. If correct mass (M/Z) values are obtained, the operator proceeds to the next tuning step. If not, Step 1 is repeated until correct masses are obtained.

2. Peak intensity ratios are set from the major peaks in the PFTBA spectrum using the following values:

Mass (M/Z)	Spectrum Intensities
69	= 100%
131	= 25% +/- 5%
219	= 35% +/- 5%
502	= 5% +/- 2%

3. During tuning, the ion signal for mass (M/Z) 69 of PFTBA is measured at a specific sample pressure and detector voltage and compared to previous operation values.

4. Electron energy (meter reading) is set to 15 electron volts and emission is set at 12 milliseconds. All other operating parameters, such as scans, scan range, mass offset are established in the computer program. These values (sensitivity) can only be changed by the laboratory manager.

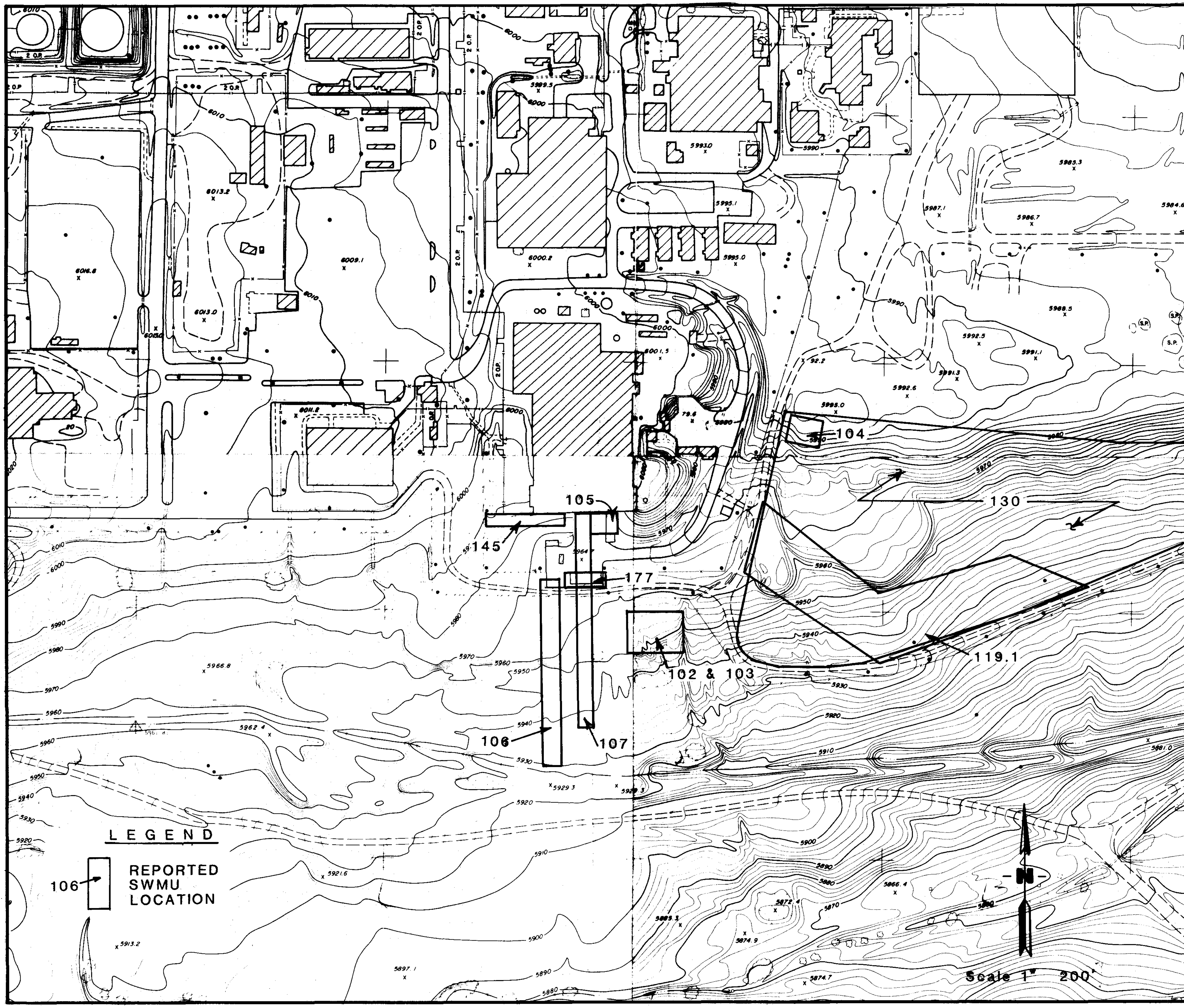
5. Final detector voltage is established using the duplicate collector field sample.

MASS SPECTROMETER ANALYSIS

1. Periodic (approximately every 20 samples) machine background analyses are performed to assure minimal influence from internal communication. If there are peaks that are not related to atmospheric gases, the supervisor is notified and the mass spectrometer is shut down and cleaned as necessary.

2. A written sample number record is kept during the analysis to prevent accidental cross numbering.

3. The mass spectrometer control program contains appropriate "flag statements" that prompt the operator with a warning if an inputted sample number has already been analyzed. The operator then checks the current number, along with the disk storage location of the previously entered number, to identify the true numbering situation.



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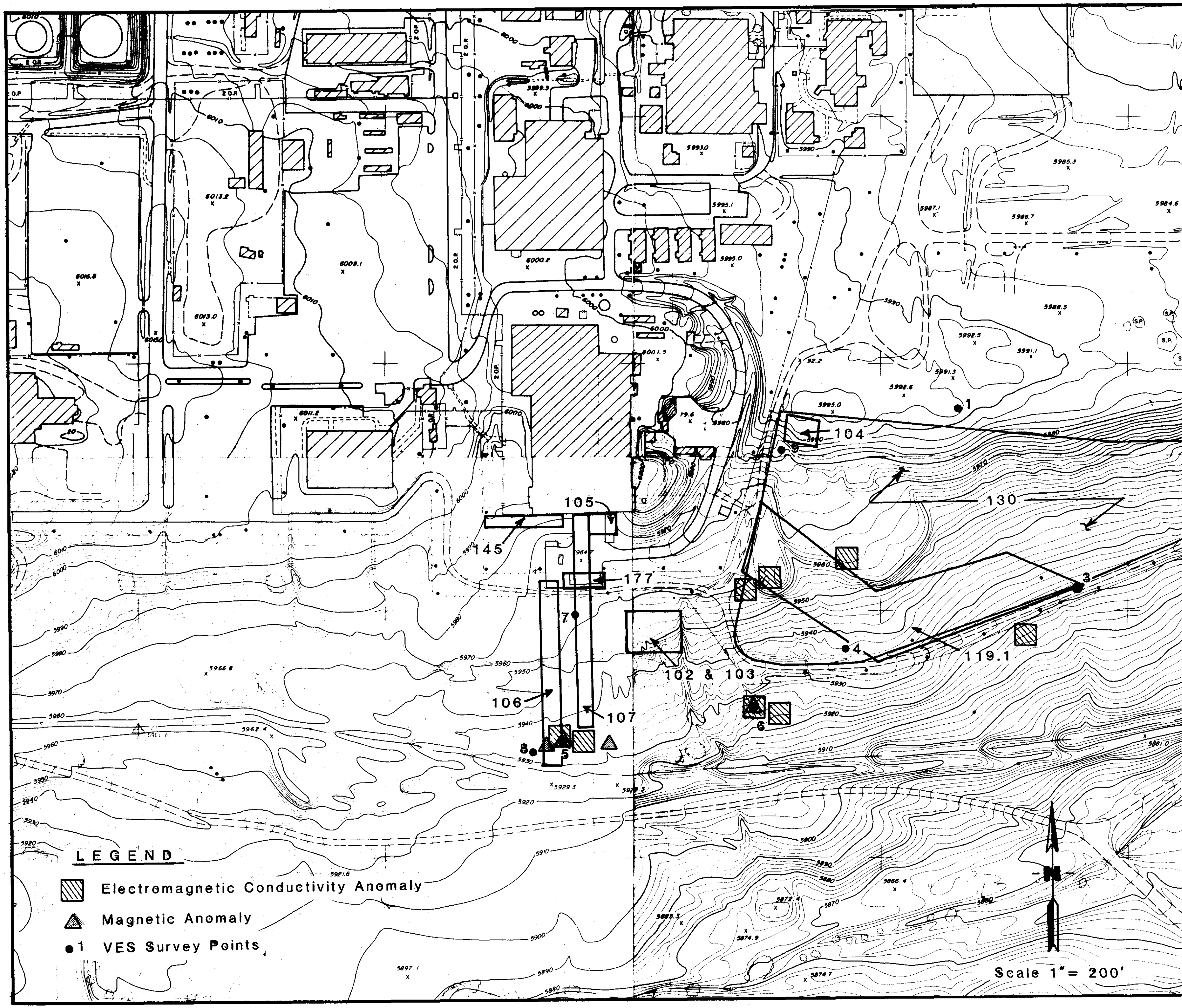
REPORTED LOCATION OF 881 HILLSIDE SWMUS

FIGURE 1



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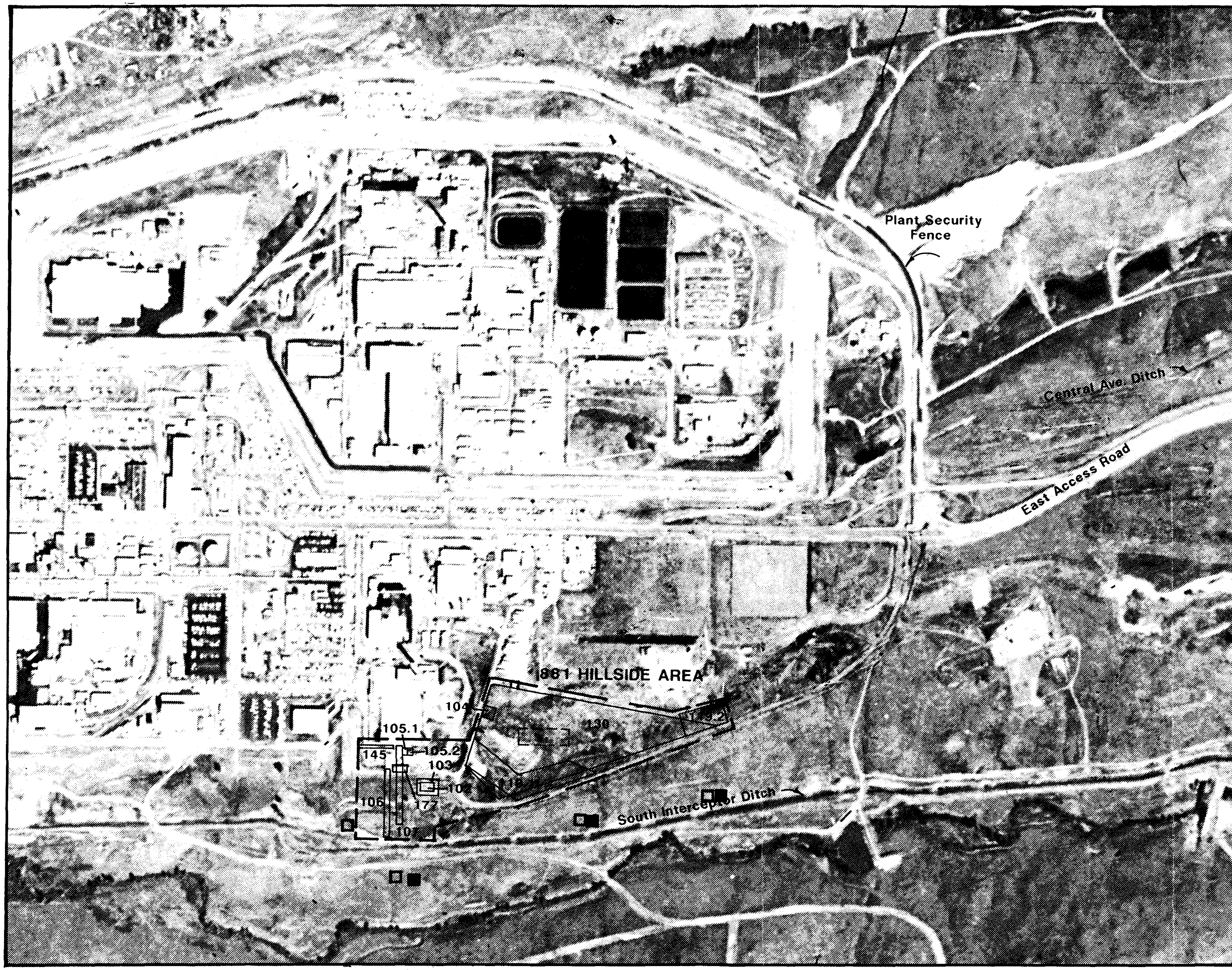
LOCATION OF GEOPHYSICAL ANOMALIES AND VES SURVEY POINTS

FIGURE 2



EXPLANATION

- □ Proposed Alluvial Well
- ■ Proposed Bedrock Well
- ○ Initial CEARP Phase 2 Alluvial Well
- ● Initial CEARP Phase 2 Bedrock Well
- △ Existing Wells from Previous Investigations
- Location of Solid Waste Management Unit
- Location of Areas of Interest Within Solid Waste Management Unit
- 101 Solid Waste Management Unit Reference Number (Rockwell International, 1986a)

NOTES:

1) Base map photo-enlarged from aerial photography of Rocky Flats Plant taken May 20, 1986.

2) The locations of the solid waste management units have been located as accurately as possible, based on information available prior to 1987 remedial investigation.

1" = 500'

0 500' 1000'

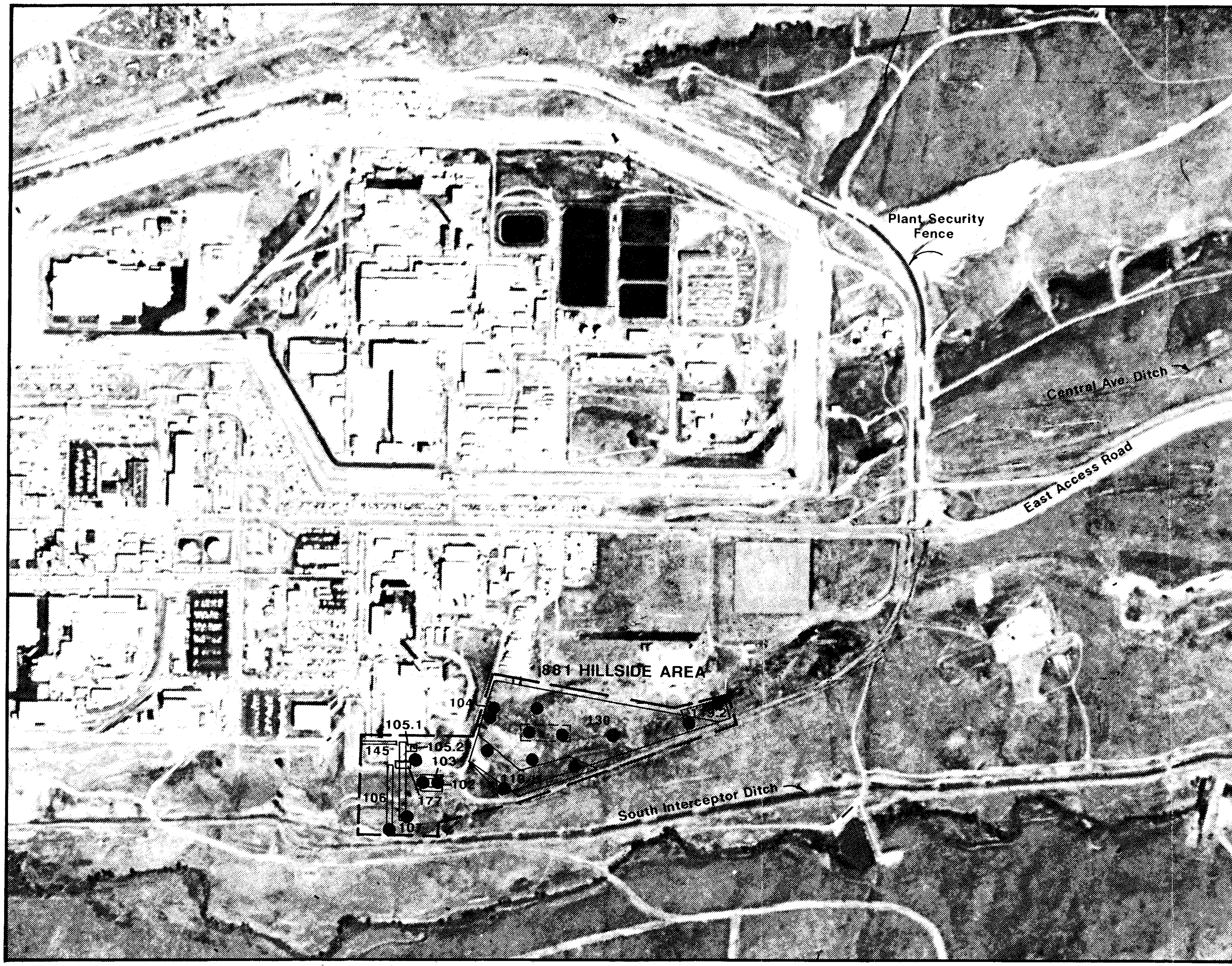
PLATE IV:

881 Hillside Area

Remedial Investigation

Existing and Proposed Monitor Well Locations

March 1, 1988



-N-

EXPLANATION

● Proposed Soil Boring Locations

☐ Location of Solid Waste Management Unit

⬚ Location of Areas of Interest Within Solid Waste Management Unit

101 Solid Waste Management Unit Reference Number (Rockwell International, 1986a)

NOTES:

1) Base map photo-enlarged from aerial photography of Rocky Flats Plant taken May 20, 1986.

2) The locations of the solid waste management units have been located as accurately as possible, based on information available prior to 1987 remedial investigation.

1" = 500'

0 500' 1000'

PLATE III:

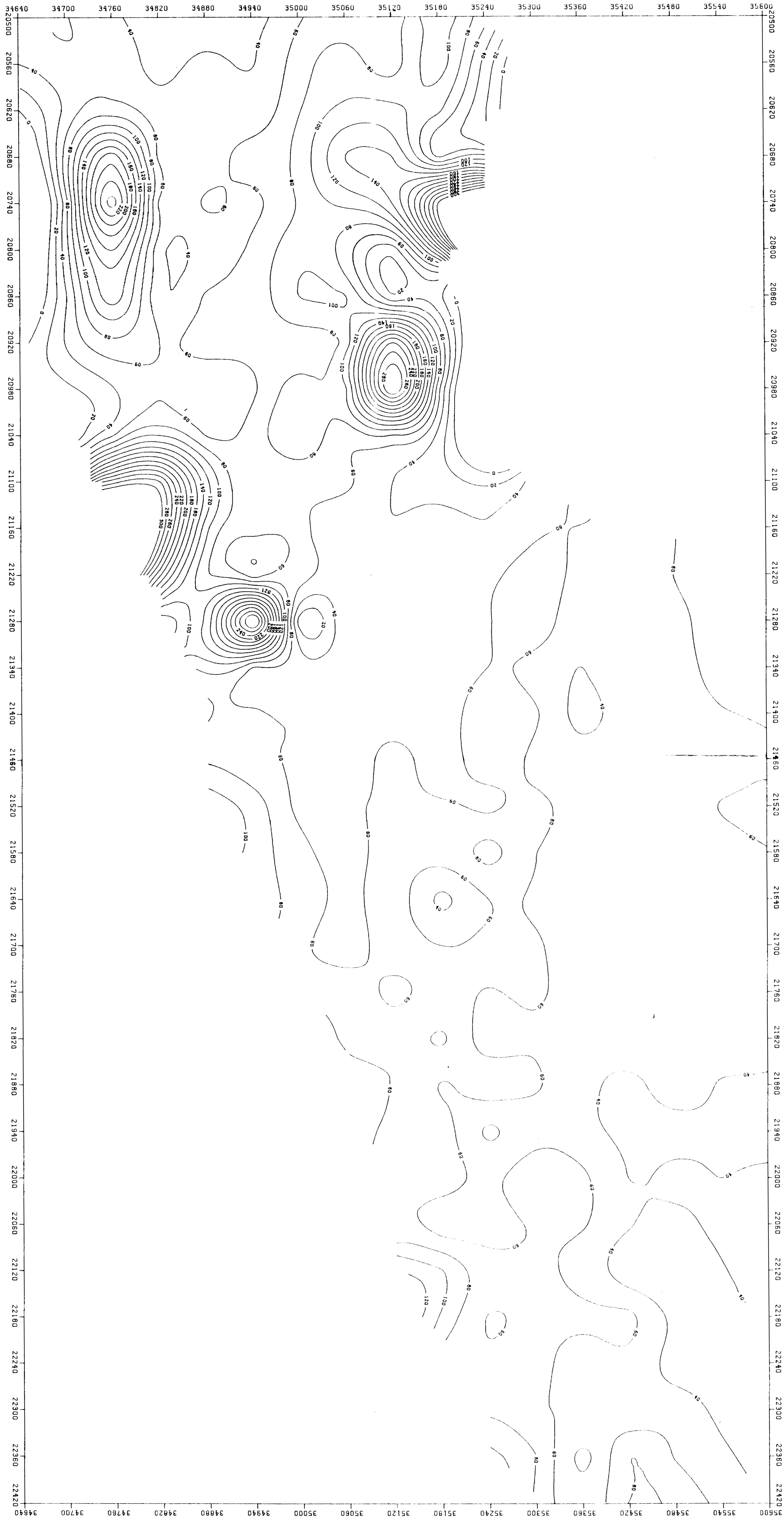
881 Hillside Area

Remedial Investigation

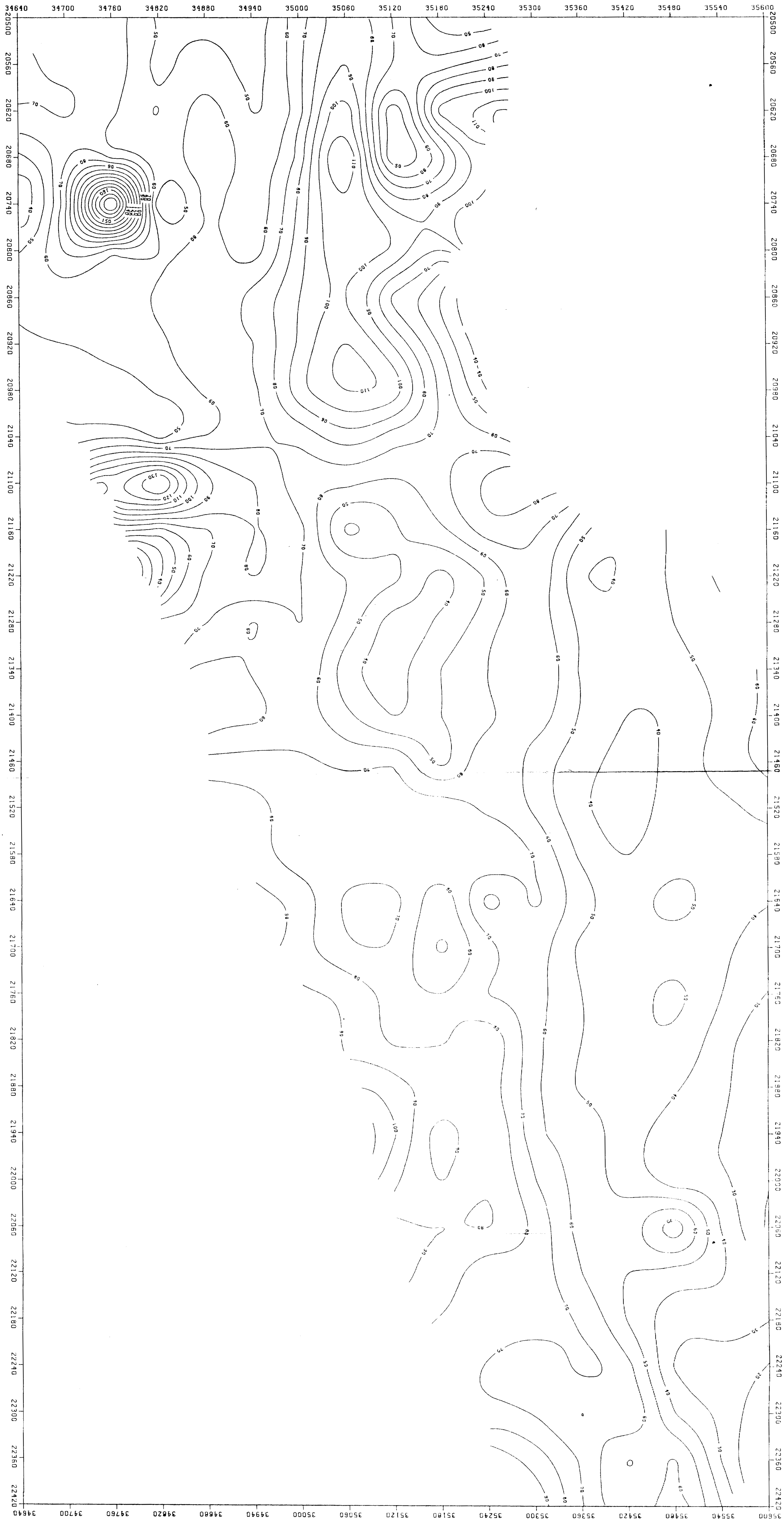
Proposed Soil Boring Locations

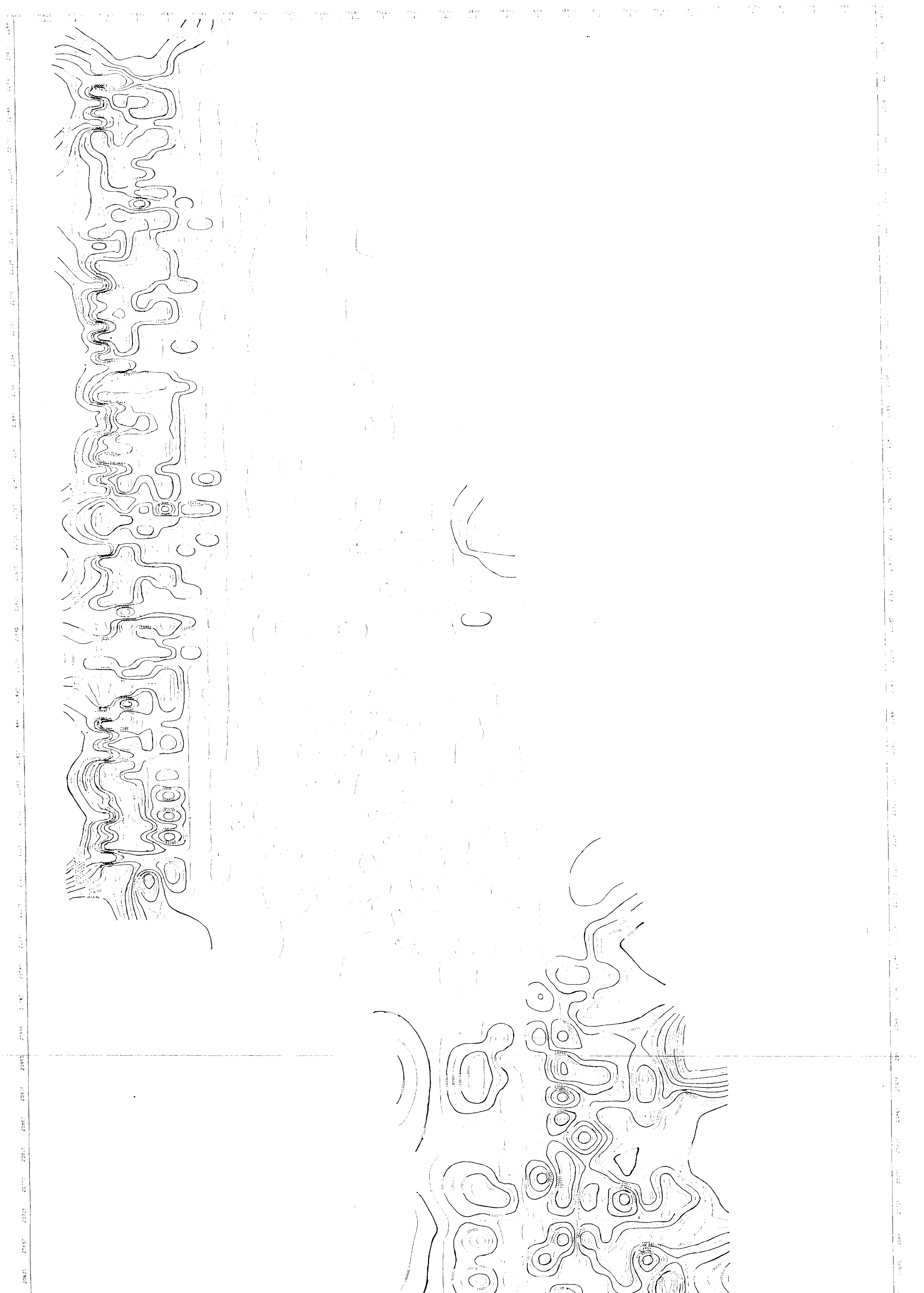
March 1, 1988

ROCKY FLATS 881 HILLSIDE - EM34 VERTICAL DIPOLE (4/14/87)



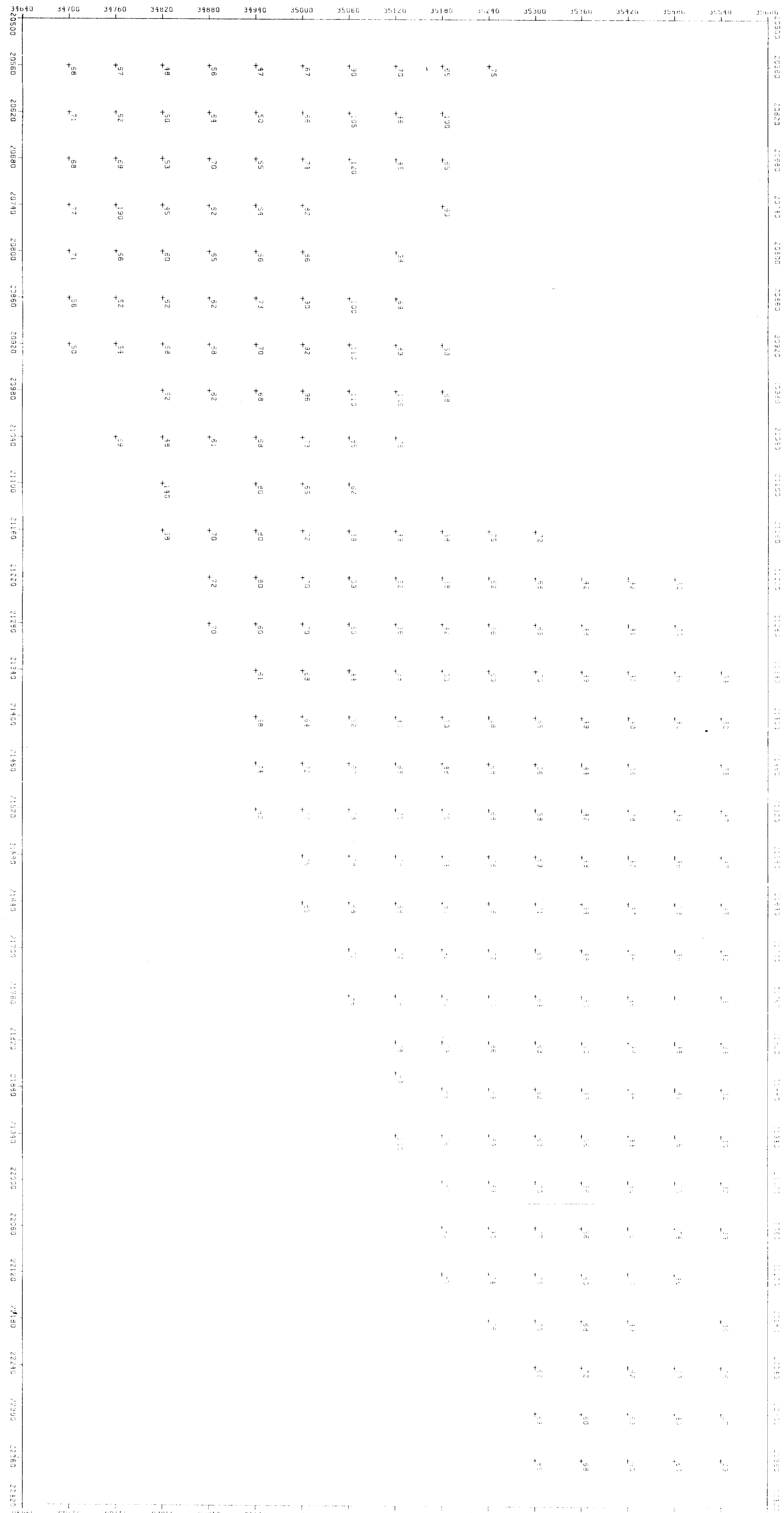
6.000:1 RØCKY FLATS 881 HILLSIDE - EM34 HØRIZØNTAL DIPØLE (4/14/87)

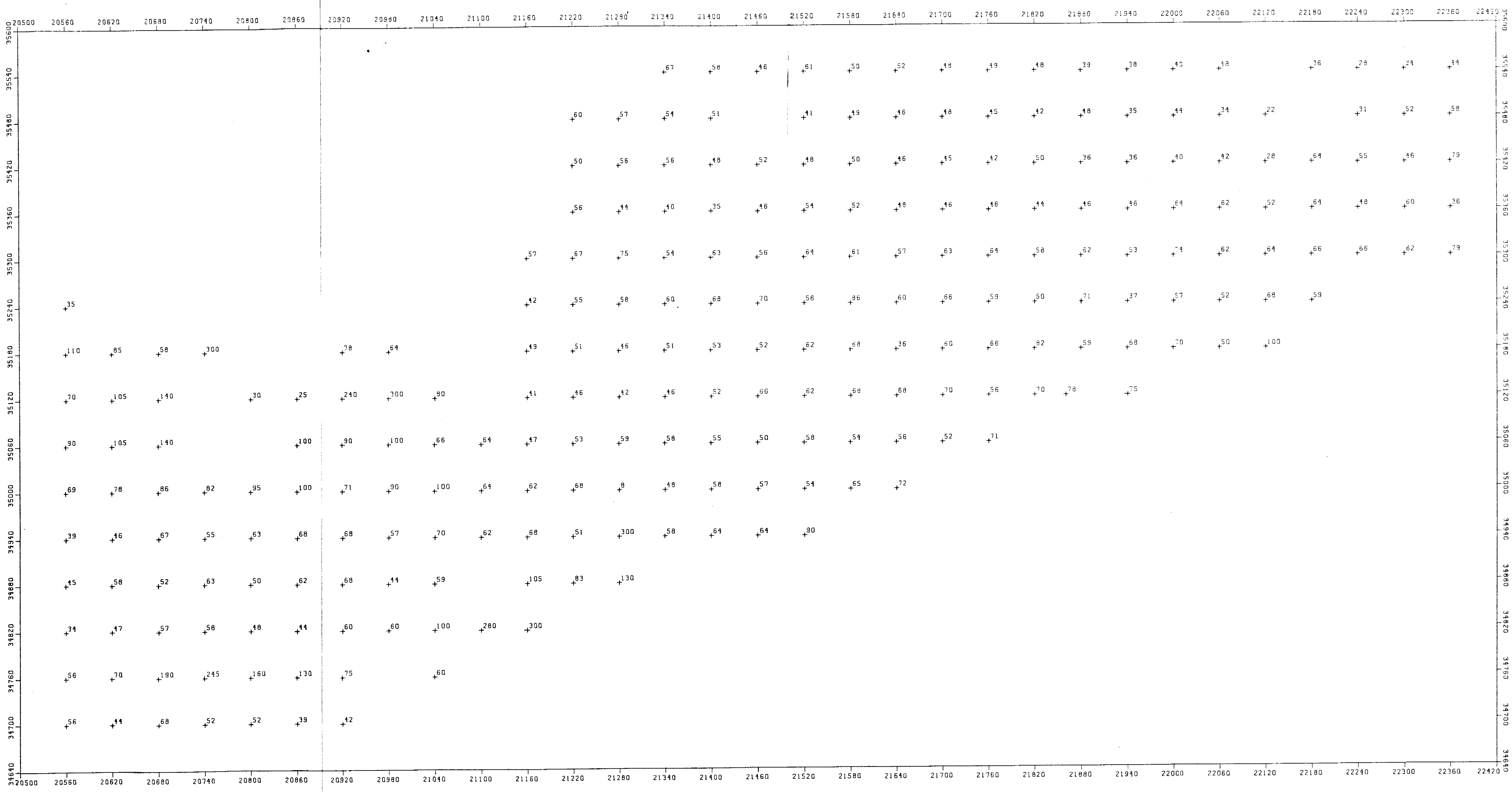




6.000

RØCKY FLATS 881 HILLSIDE - EM34 HØRIZØNTAL DIPØLE PØST (4/14/87)

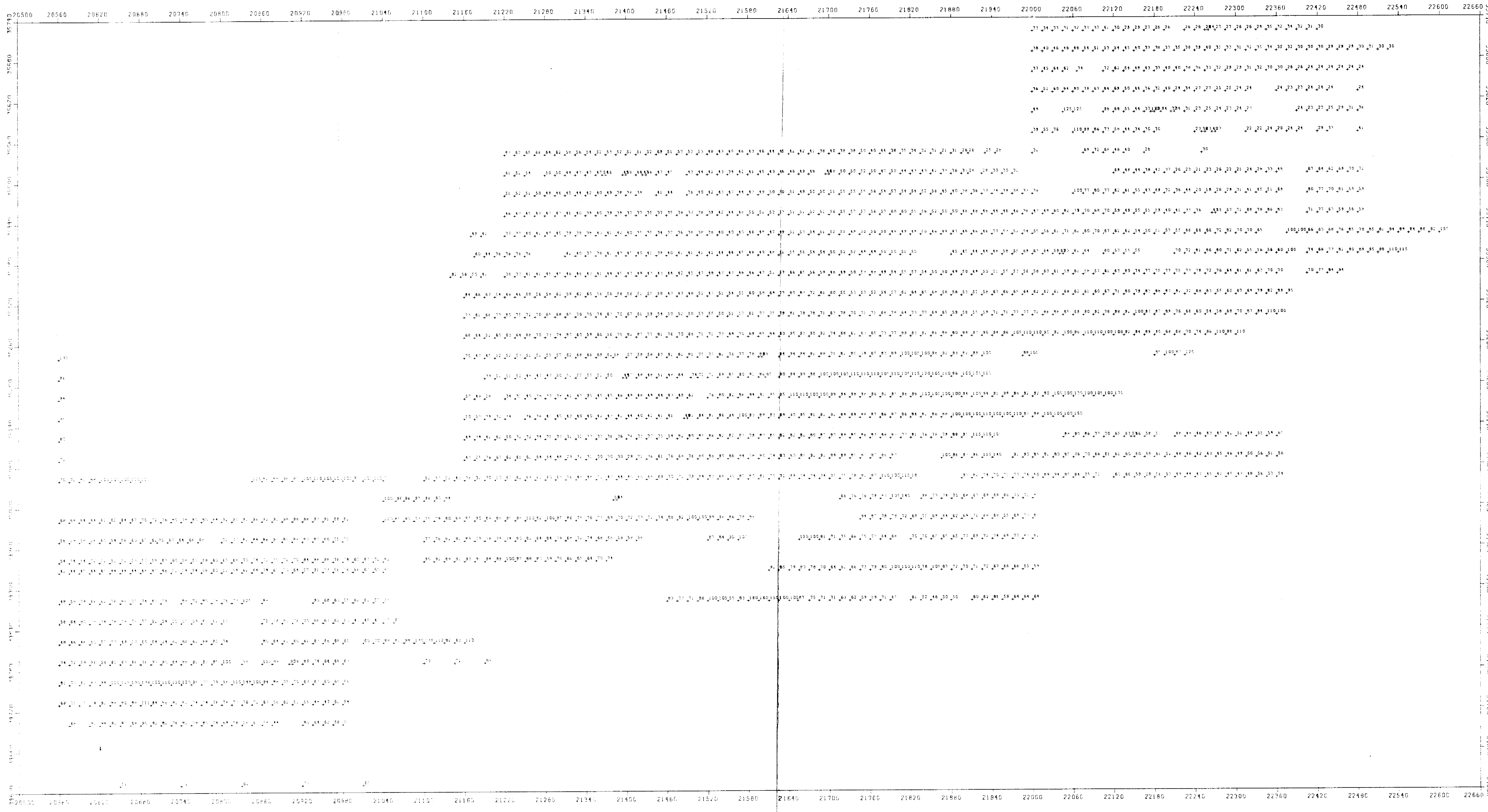




RØCKY FLATS 881 HILLSIDE - EM39 VERTICAL DIPØLE PØST (9/19/87)

6.000+1

ROCKY FLATS 881 HILLSIDE EM 31 DATA



000.1

ROCKY FLATS 881 HILLSIDE - EM 31 DATA (PART TWO)